THE

PANORAMA

OF

SCIENCE AND ART;

EMBRACING

THE PRINCIPAL SCIENCES AND ARTS; THE METHODS OF WORKING IN WOOD AND METAL; AND A MISCELLANEOUS SELECTION OF USEFUL AND INTERESTING PROCESSES AND EXPERIMENTS.

BY JAMES SMITH.

IN TWO VOLUMES, WITH ILLUSTRATIVE ENGRAVINGS.

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PNEUMATICS.

THE science of Pneumatics treats of the density, pressure, and elasticity of the air, and the effects which they produce.

The air is the fluid in which we live and breathe; it entirely envelops the globe, and extends to an unknown height above its surface. It is, together with the clouds and vapours that float in it, called the *atmosphere*.

Anciently, the air was almost universally supposed to be destitute of weight: Galileo was the first who proved, by experiments, the fallacy of this supposition; and it is now sufficiently manifest, that, like all other fluids, it presses upon bodies in proportion to the depth they are immersed in it, and that the pressure is in every direction, or on all sides of such bodies. It differs from water and other visible fluids in the four following particulars: 1. It can be compressed into a much less space than it naturally possesses. 2. It cannot be congealed or reduced to a solid state. 3. It is of a different density in every part upwards from the earth's surface, decreasing in its weight as its distance from the earth increases. 4. Its elasticity, or the force with which it springs, is equal to the incumbent weight.

The air being perfectly invisible, and affording no resistance to the touch, it is not surprising that, according to vulgar apprehension, it should not be considered as a solid and material substance; and yet that it possesses weight, and great power of resistance to other bodies, many simple experiments may be devised to prove. A bladder, open at the aperture of the neck, may have its sides pressed together with the greatest

easy, but if this bladder is filled by blowing air into it, and a string is then tied fast round the neck, it becomes impossible to press its sides together without breaking the bladder, and a very slight alteration of its figure requires considerable pressure. The resistance thus perceived, evidently proves that air contains solid particles.

Again, we are accustomed to say, that a vessel is empty, when we have poured out the water it contained; but throw a bit of cork upon a basin of water, and having put an empty tumbler over it, with the mouth downwards, force it through the water, the cork will shew the surface of the water within the tumbler, and it will be found not to rise so high within as without the glass; nor, if pressed ever so hard, will it rise to the same level. The water is therefore prevented from rising within the tumbler, by some other substance which already occupies the inside. This substance is the air in the tumbler, which, thus situated, cannot escape, on account of the superior pressure of the water. In like manner, when the nozzle of a pair of expanded bellows is stopped, if the valve and fittings are perfectly close, the bellows cannot be shut; and though the side may be pressed rather nearer, they will, from the elasticity of the air they enclose, regain their original distance, as soon as left to themselves.

It is the great *transparency* of the air, which, in the common acceptation of the term, renders it invisible; but the blue colour of the sky may be considered as the colour of the air, for this blueness is occasioned by reflected light. If the atmosphere were absolutely transparent, it would reflect no light; every object which did not receive the direct rays of the sun, would then be in total darkness, and the stars would be visible at mid-day.

According to the average of many experiments which have been made with the greatest care, the weight of water is to that of air as 832 to 1, when the barometer is at 30°, and the thermometer at 55°. A cubic foot of air may be taken at 1¼ ounce, of water at 1000 ounces, and quicksilver at 13,600 ounces. The pressure of the atmosphere sustains, in the tube of a barometer, a column of mercury about 30 inches in height; it accordingly follows that the whole pressure of the atmosphere on any given space, is equal to the weight of a column of mercury on an equal base, and 30 inches in height, or the weight of the atmosphere, on every square inch of surface, is equal to about 15 pounds. It has also been repeatedly proved, that the pressure of the atmosphere balances a column of water about 34½ feet high; and the cubic foot of water weighing just 1000 ounces, or 62½ pounds, 34½

multiplied by 62½, the product of which will be 2156 pounds, is the weight of a column of water, or of a column of the atmosphere, the base of which is a square foot. Hence the pressure of the atmosphere on the whole surface of the earth has been calculated to be equivalent to that of a globe of lead 60 miles in diameter. Dr. Vince and others have estimated the weight at 77,670,297,973,563,429 tons.

As the lowermost parts of the atmosphere are pressed by the weight of all those that are above them, it follows that the air must be more dense and compact at the earth's surface than at any height above it, and that its rarity will increase with the elevation. Dr. Cotes has demonstrated, that if altitudes in the air be taken in arithmetical proportion, the rarity of the air will be in geometrical proportion. For instance, at the height of 3½ miles, the rarity of the atmosphere is nearly twice as great as at the surface of the earth; at the height of 7 miles, 4 times rarer; and so on; hence the construction of the following table:

At the height of		miles above the earth, the air is		times rarer.
	3½		2	
	7		4	
	14		16	
	21		64	
	28		256	
	35		1024	
	42		4096	
	49		16384	
	56		65536	
	63		262144	
	70		1048576	
	77		4194304	
	84		16777216	
	91		67108864	
	98		268435456	
	105		1073741824	
	112		4294967296	
	119		17179869184	
	126		68719476736	
	133		274877906944	
	140		1099511627776	

By this mode of calculation it might be shewn, that a cubic nch of the air we breathe, would be so much expanded or rarefied at the height of 500 miles, that it would fill a sphere equal in diameter to the orbit of Saturn. We have observed,

in another place, that at the height of forty-five miles, the air begins to have the power of refracting a ray of light, but meteors, which, it might be supposed, require air for the support of their combustion, have been observed at much greater elevations.

The pressure of the atmosphere is removed, for philosophical purposes, by means of the *air-pump*. With this machine, a great variety of interesting experiments may be performed, in proof of the properties of the atmosphere; without it, indeed, pneumatics would scarcely deserve the name of a science. Its construction has been much diversified by ingenious men; but the form of it we shall now describe has obtained very general acceptance.

Fig. 1, pl. I, on a square frame, AB, of well-seasoned mahogany, is placed a circular brass plate G. This plate should be a perfect plane, free from scratches, or other imperfections. It may be made according to the direction we have already given for forming flat surfaces; and it is proper to observe, as well to those who intend to purchase, as to those who may wish to construct an air-pump, that if the plate G be not well made, it will be a fruitful source of inconvenience. CC are two brass barrels, each containing a piston, with a valve opening upwards; the pistons are worked by means of the winch P, on the axis moved by which, there is a pinion or small wheel that fits into the teeth of the racks DD, which are affixed to the upper ends of the pistons, and by this means the pistons are moved up and down alternately. A brass tube, communicating with the two barrels and the stop-cock *b*, is let into the wood, and opens into the centre of the brass-plate at the apex of the additional piece *d*.

The glass vessel M, to be emptied or exhausted of air, and which is called a receiver, is ground quite flat on the rim, in order that it may so closely fit the brass plate of the pump, as, when placed upon it, to be air-tight. In order, however, to prevent the failure of an experiment, from imperfections of workmanship, or the accidental interposition of particles of dust, &c. the rim of the receiver is rubbed with a little pomatum, hog's lard, or tallow, and when placed on the plate G, it is moved once or twice backward and forward, for a very short distance, as a quarter of an inch, and it is pressed downwards at the same time. When the receiver is properly placed, and the cock *b* is shut, the pistons are worked by the winch, and as the air escapes when a piston is forced down, because the valve of the piston opens upwards, and closes by the external pressure of the atmosphere when the piston is forced upwards, the receiver is gradually exhausted, and

becomes immoveable upon the pump-plate. By opening the cock *b*, the air rushes again into the receiver, which is then loosened, and may be removed.

It was formerly common, and the practice is not yet wholly given up, to lay a piece of leather soaked in water or oil on the pump-plate, in order to make the receiver air-tight; but this is a slovenly and inconvenient practice, which good workmanship renders wholly unnecessary. In using the air-pump, every substance containing moisture should be removed from the pump-plate, as water and other fluids give out or assume the form of an elastic vapour, when the pressure of the atmosphere is removed.

To shew more distinctly the manner in which an air-pump is caused to act, the wheel and racks, with the barrels and valves, are represented separately in fig. 2. At the bottom of each barrel is a valve, which is a piece of leather or any other substance, covering a hole, and opening only one way, as for instance, like the flapper of a pair of common bellows, which opens to admit the air, but suffers none to pass out. In the air-pump, the valves *a* and *b* open upwards, and require for that purpose only a very slight impulsion. The bores of the cylinders XY, are made as accurately cylindrical as possible, and are exactly filled by the short cylinders or pistons *e f* attached to the respective racks. The circumferences of the pistons are covered with a thin piece of oiled or greased leather, to make them completely air-tight, and they are furnished with valves like those at the bottom of the barrels, and opening the same way. Supposing the rack Q to be depressed to its lowest situation, its piston will lie upon the bottom of the cylinder; turn then the handle from *l* towards *m*, and the rack Q will attain the position represented by the rack P in the barrel X. The space thus made between the piston and the bottom of the cylinder, would be a vacuum, if there were no openings into it; but the spring of the air in the receiver, causes that fluid to rush along the pipe communicating with the barrels, and opening the valve *b*, to fill the space between that valve and the piston. As soon as this has been accomplished, it is obvious, that the air in the receiver is not so dense as it was, because it occupies a greater space. In proceeding with the experiment, the handle is turned back from *m* towards *l*, where it was at first; and as the air which had rushed through the valve *b*, to fill the vacuum that had been made by raising the piston *f*, cannot open the valve *b*, and be forced again into the receiver, it will, on the depression of the rack Q, force open the valve in the piston *f*, and escape; then when the rack Q is raised a second time, the air by its spring again fills the

space between the two valves, and therefore suffers a second diminution in the receiver. In this manner both barrels act, one rack being up while the other is down, and the operation is continued till the spring of the air in the receiver is no longer sufficient to lift the valves *a b*, when the operation of pumping the air out of the receiver must cease; and in most experiments it is by no means carried so far.

It is evident from the preceding account of the construction of an air-pump, that the vacuum in the receiver can never be perfect, that is, the air can never be entirely exhausted; becaus s the spring only of the air in the receiver, that ra he valve, and forces air into the barrel, and the barrel, at each stroke, can only take away a certain part of the remaining air, which is proportioned to the quantity before the stroke, as the capacity of the barrel is to that of the barrel and receiver added together. This imperfection, however, is seldom of much consequence in practice, because most air-pumps, at a certain period of the exhaustion, cease to act on account of their imperfect construction; for the valves usually consist of a piece of oiled bladder, and there is unavoidably a small space left between the lower valve and the piston when down. Also, when the air in the receiver is very rare, its spring will not be sufficient to overcome the adhesion of the bladder forming the lower valve, which consequently will remain shut, and the exhaustion will stop, while the spring of the air yet remains adequate to lift the weight of the valve. Or, before this takes place, it may happen, that the air between the valves when the piston is up, may be so rare as to lie in the space between the two valves when the piston is down, without being sufficiently condensed for its spring to overcome the adhesion of the bladder forming the upper valve, and the weight of the atmosphere that presses upon it: in this case the upper valve will remain shut, and the progress of the exhaustion will cease.

To improve the air-pump, Smeaton enlarged the size of the lower valve, which he supported on a brass grating resembling a honeycomb. By this means the valve rose more easily. He also covered the top of the barrel, making the piston work through a collar of leathers, by which contrivance he took off the pressure of the atmosphere from the piston-valve, so that the rarefied air below it, would raise it much more readily than before. Air-pumps on this construction have been found to answer extremely well. Air-pumps have also been made with glass barrels, and tin pistons, which have had very little friction, and been remarkable for their excellence.

To the air-pump is attached the gauge, F, or instrument for measuring the degree in which the air is exhausted or rarefied in the receiver. If a barometer be included beneath the receiver, the mercury will remain at the same height as in the open air, until the exhaustion is begun by working the winch, when it will begin to descend. At any stage of the operation it will remain at a height, bearing the same proportion to its original height, as the spring of the air remaining in the receiver is to its spring before exhaustion. Thus, if the height of the mercury after exhaustion, is the thousandth part of what it was before, the air in the receiver is said to be rarefied one thousand times. As the length of the barometer renders the use of it inconvenient, a tube of six or eight inches in length, is filled with mercury, and inverted in the same manner as the barometer; it answers the same purpose, with this difference only, that the mercury does not begin to descend till after about three-fourths of the air is exhausted; it is called the *short barometer gauge,* and is generally placed detached as in the figure, but communicating with the receiver by a tube let into the frame AB. Sometimes a tube of a greater length than the barometer, with its lower end in a vessel of mercury, is exposed to the pressure of the air, while its upper end communicates with the receiver. Here the mercury rises as the exhaustion proceeds, and the pressure of the remaining air is shewn by the difference between its height and that of a barometer in the room; this is called the *long barometer gauge:* it is not, however, so convenient and suitable an instrument for general use as the former. If the tubes of these gauges be less than half an inch in diameter, the mercury will be sensibly repelled downwards, so as to require a correction for the long gauge when compared with a barometer, whose tube is of a different bore, and to render the short gauge useless in great exhaustions. For example, if the short gauge have a tube of one-tenth of an inch diameter, the mercury will fall to the level of the basin, when the exhaustion is one hundred and fifty times, and will stand below the level for all greater degrees of rarefaction. To obviate these difficulties in some measure, the short gauge may be made in the form of an inverted syphon, with the short leg open, and the other hermetically sealed. To form a good gauge, the mercury should be in as pure a state as possible.

Smeaton invented a gauge which greatly excels the short barometer gauge, and which, from its form, is called the *pear-gauge.* It consists of a pear-shaped glass vessel, see fig. 3, sufficiently capacious to hold about half a pound of mercury. It is open at one end, and at the other end is a tube hermeti-

cally closed at the top. The tube is graduated so as to represent proportionate parts of the whole capacity. This gauge, during the exhaustion of the receiver, is suspended in it by a piece of wire over a cistern of mercury, also placed under the receiver. When the pump is worked as much as is thought necessary, the gauge is let down into the mercury, and the air re-admitted.—The mercury will immediately rise in the gauge; but if any air remained in the receiver, a certain portion of it will be in the gauge; and as it will occupy the top of the tube above the mercury, it will shew by its size the degree of exhaustion; for the bubble of air will be to the whole contents of the gauge, as the quantity of air in the exhausted receiver is to an equal volume of common atmospheric air. If the receiver contain any elastic vapour, generated during the rarefaction, it will be condensed upon the re-admission of the atmospheric air, as it cannot subsist under the usual pressure. The pear-gauge therefore shews the true quantity of atmospheric air left in the receiver. Hence it will sometimes indicate that all the permanent air is exhausted from the receiver, except about a hundred thousandth part, when the other gauges do not shew a degree of exhaustion of more than two hundred times.

When a receiver is placed upon the plate of the air-pump, without working the winch, it may of course be removed again with as much facility as if placed upon any other surface, because the air it contains resists, by its elasticity, the pressure on the outside; but let this counter-pressure be removed, by working the winch backwards and forwards, so as alternately to raise and depress the racks, and the receiver is found to be held down to the plate by a very strong force. The nature of this force may be easily understood by the following considerations: When the surface of a fluid is exposed to the air, it is pressed by the weight of the atmosphere equally on every part, and consequently remains at rest; but if the pressure be removed from any particular part, the fluid must yield in that part, and be forced out of its situation. Into the receiver A, fig. 4, pl. I, put a small vessel with mercury, or any other fluid, and through the collar of leathers at B, have a wire to suspend a glass tube hermetically sealed, over the small vessel. Having exhausted the receiver, let down the tube into the quicksilver, which will not rise into the tube as long as the receiver continues empty; but re-admit the air, and the quicksilver will immediately ascend. The reason of this is, that upon exhausting the receiver, the tube is likewise emptied of air; and therefore, when it is immersed in the mercury, and the air re-admitted into the receiver, all the surface of the mercury is pressed upon by the air, except that portion which is covered by the

orifice of the tube, consequently it must continue to rise in the tube until the weight of the elevated mercury presses as forcibly on that portion which lies beneath the tube, as the weight of the air does on every other equal portion without the tube. The rising of water in a common syringe, when the piston is drawn up, is owing to the same cause as the rising of the mercury in this experiment; the pressure of the atmosphere being removed from that part of the water opposed to the aperture, the water is obliged to yield in that part by the pressure on the rest of its surface. It is upon the same principle that all those pumps called sucking-pumps act.

The elastic power of the air is always equivalent to the force which compresses it, action and re-action being always equal; so that the elastic force of any small portion of the air we breathe, is equal to the weight of the incumbent part of the atmosphere; that weight being the force which confines it to the dimensions it possesses. To prove this by experiment, pour some mercury into the small bottle A, fig. 5, pl. I, and screw the brass collar C, of the tube BC, into the brass neck of the bottle, and the lower end of the tube will be immersed in the mercury, so that the air above the mercury in the bottle will be confined there. This tube is open at the top, and is covered by the receiver G, and the large tube EF, which tube is fixed by brass collars to the receiver, and is closed at the top. This preparation being made, exhaust the air out of the receiv G and its tube, by putting it upon the plate of the air-pu..p, and the air will, by the same means, be exhausted out of the inner tube BC, through its open top, at B. As the receiver and tubes are exhausting, the air that is confined in the glass bottle A, expands, and pressing upon the mercury in the inner tube, will raise it as high as it stands in the barometer.

When it had once become known that the air is possessed of weight, it may be thought that it could not have been very difficult to account for some of its more remarkable effects, such as the ascent of water in the body of a pump. The contrary, however, appears to have been the case. Some Italian artists having received orders to construct a common pump for the purpose of raising water to the height of 50 or 60 feet, found, to their astonishment, that about 33 feet was the limit to which the water would rise. Galileo was applied to for an explanation of this circumstance, and as he had adopted the current opinion of the age, that the only reason why water rose at all in pumps was nature's abhorrence of a vacuum, so to this inquiry he is said to have answered, that nature did not entertain the horror of a vacuum beyond 33 feet! Galileo had

afterwards reason to suppose that he had not given a very philosophical answer to the question put to him, but Torricelli, a pupil of his, was the first who conjectured that water is elevated in pumps by the pressure of the exterior air; and that the amount of this pressure can counterbalance no more than a column of water 33 feet high. He instituted an experiment, that at once verified his conjecture, and proved the origin of that important invention, the barometer. He took a glass tube, of about three feet in length, and two or three lines in diameter, hermetically sealed at one end, and open at the other; he filled it with pure mercury, and stopping the orifice with his finger, he reversed the tube, and placed the open end in a vessel full of the same mercury. He had no sooner removed his finger, than the column of mercury, which was about thirty-six inches long, was reduced to the length of about 28 inches. This height being to that of 33 feet, in the inverse ratio of the densities of water and mercury, he concluded that, as he had conjectured, it was the pressure of the air which caused both water and mercury to rise until an equilibrium was produced. The experiment thus tried, is called the Torricellian experiment, and the space left at the top of the tube, is called the Torricellian vacuum. It is the nearest approach to perfect vacuum which the art of man can form, and is much superior to that of the best air-pump. Soon after the experiment became known, Pascal suggested that the proof of the theory grounded upon it, might be obtained, by trying whether the mercury remained at different heights at different altitudes, as for instance, at the foot and the summit of a lofty mountain. Upon the trial being made, it was found that the variation required by the theory actually occurred. This fact being fully established, the idle chimera, to conceal ignorance, which assumed as facts nature's horror of a vacuum, or the contrary, disappeared for ever.

The pressure of the atmosphere is not always the same at the same place. These changes take place chiefly in countries at a distance from the equator. In Great Britain, the height in inches of the mercury in the barometer, varies from 28.4 to 30.7. It has been known to vary more than an inch in a few hours. Supposing the surface of a middle-sized man, equal to 14½ square feet, the pressure upon him, when the atmosphere is lightest, is equal to 13½ tons, and when heaviest, it is about 14½ tons, the difference amounting to about 1866 pounds. The immense pressure we sustain does not impede our motions, because the pressure on one side is balanced by an equal pressure on the opposite side, or, in other words, the pressure is on all points the same; nor is it capable of crushing the human

frame, because the elastic force of the air, or of other elastic fluids within the body, is just sufficient to resist every injurious effect. We know that the human body contains elastic fluids, that require the usual pressure of the atmosphere to prevent their expanding and thereby endangering life, because at the tops of very high mountains, the blood sometimes gushes from the lungs, the nose, and other parts covered only by delicate membranes, which are easily burst. So far then from the pressure of the atmosphere being a disadvantage, it is evidently indispensable; and we even find, that our frame is braced, and that we are never more alert and active than in clear and fine weather, when the mercury stands highest, and consequently the pressure of the atmosphere is greatest; on the contrary, when the mercury falls, and the weight of the air diminishes, we feel listless and uncomfortable. Of the effects resulting from changes in the weight of the atmosphere, invalids are often susceptible in a distressing degree.

Before we proceed to describe a course of experiments, which are usually exhibited with the air pump, it will perhaps be acceptable if we give the simplest form of this machine, by which the experiments alluded to, and others of a similar nature, may be performed as well, so far as regards the effect, as by the more costly and complex apparatus.

In fig. 6, MN is an oaken or mahogany board, 16 inches long, 8 broad, and 1¼ thick. G is a cylinder or tube of brass or tin, 7 inches long, and 1¼ diameter. K is a solid plunger or piston, covered with oiled leather to make it perfectly air-tight. Into the plunger is screwed a strong wire, with a handle at the end H, by which the plunger may be pulled up, or thrust down, at pleasure. At L is a stop-cock, which is more distinctly represented at fig. 7. The middle circumference, AB, is divided into four equal parts;—through one of the divisions is drilled a small hole to the centre of the cock D, and from the centre of the lower end E, is drilled a passage to meet the former in D. Also, from two of the opposite divisions, A and B, are drilled two passages to meet above the centre in C. Through the fixed part of the stop-cock, must be drilled passages meeting the ends AB, of the passage ACB. The end B, of the stop-cock, is soldered or screwed into the end of the tube G. F is a circular piece of tin-plate or brass, six inches in diameter. FI is a half cylinder of brass, 3½ inches long, and a quarter of an inch in diameter, soldered to the underside of the plate F, if that be tin, or cast along with it, if it be brass, which is most suitable for the purpose. A passage is drilled from the end I to the centre F; and through the centre of the plate F, a hole is made to meet this passage. The end I

of the half cylinder, must be screwed into the immoveable part of the stop-cock, so as to connect the passages. The cylinder G must then be let neatly into the board MN, so that the plate F may rest evenly upon its surface, and be properly secured.

If the plate F, in this pump, be made of tin-plate, it will not be accurately flat, in which case it will be necessary to cover it, except at the aperture in the centre, with a leather soaked in water or oil: the plate F should therefore be made of brass, and ground true like those of the best air-pumps, so that a little hog's lard, round the rim of the receiver, will prevent the access of air. When the receiver has been adjusted, fix the handle of the stop-cock in the direction IK; draw up the piston K, and the air will rush out of the receiver through the passages into the cylinder G. Then turn the head of the stop-cock IK into the direction L *o*, push in the piston, and the air will be forced out of the cylinder through the passage DE of the stop-cock. Again, place the top of the cock in the direction IK, pull up the piston K, and more air will rush out into the cylinder G, which must be forced through the passage DE as before. To let air into the receiver, place the handle IK, of the stop-cock, in the direction *o L*, and air will rush into the receiver through the passage ED.

With this instrument may be performed all the usual experiments of pneumatics, and it possesses so much simplicity, that it may be constructed at a small expense, by workmen such as any provincial town or village will furnish.

Pneumatical Experiments by Rarefaction,

Relative to the Weight of the Air.

1. Having fitted a brass cap, with a valve tied over it, to the mouth of a thin bottle, or Florence flask, whose contents are exactly known, screw the neck of this cap upon the cone *d*, of the pump-plate, G, fig. 1: then having exhausted the air out of the flask, and taken it off from the pump, let it be suspended at one end of a balance, and nicely counterpoised by weights in the scale at the other end. When this has been done, raise up the valve with a pin, and the air will rush into the flask with an audible noise; during which time, the flask will descend, and draw down that end of the beam. When the noise is over, put as many grains into the scale at the other end, as will restore the equilibrium; and they will shew exactly the weight of the quantity of air which has been

received into the flask. If the flask holds exactly a quart, it will be found that 17 grains will restore the equipoise of the balance, when the mercury stands 29½ inches in the barometer. Hence, when the density of the air is at a mean state, a quart of it weighs 17 grains: it weighs more when the mercury stands higher, and less when it stands lower.

2. Set the small glass AB, fig. 8, which is open at both ends, over the centre of the pump-plate, and cover the top of it, at B, with the palm of one hand; then, upon exhausting the air out of the glass, the hand that covers it will be pressed down and bent into the glass, with so much force, that if the exhaustion be carried far, it will be impossible to release it, until the air is re-admitted into the glass by turning the cock *b*, fig. 1. The air admitted, by acting as strongly upwards against the hand, as the external air acted in pressing it downwards, immediately renders its removal easy. The pressure upon the hand, supposing the exhaustion to be complete, is equal to 15 pounds multiplied by the number of square inches in the upper area of the glass.

3. Tie a piece of wet bladder over the open top of the glass used in the last experiment, set it to dry, when the bladder will become tight, and equally stretched. Place the open end upon the centre of the pump-plate, and begin to exhaust the glass. As the operation proceeds, the spring of the air in the glass will be weakened, and will therefore give way to the pressure of the outward air on the bladder, which will become spherically concave on the top, and grow deeper and deeper, until the strength of the bladder be overcome by the weight of the air, when it will break with a report as loud as that of a gun. When the receiver is small, it will require some time, and a very perfect exhaustion, to succeed in this experiment; but if the bladder, when it has become very hollow, be slightly punctured with a needle, the expected effect will ensue immediately.—If a flat piece of thin glass be laid upon the open top of this receiver, and made air-tight by the interposition of hog's lard, or a ring of wet leather, as soon as the exhaustion is complete, the glass will be broken with a loud report, as in the former case. Receivers are enabled to resist the heavy pressure upon them when exhausted, by their peculiar form; an arch resisting pressure at all points nearly alike. In proof of this, it may be observed, that if the air be exhausted out of a square phial, the pressure of the atmosphere will break the phial to pieces. In trying the experiment, it is usual to cover the phial with a wire cage, to prevent any accident from the splinters of glass.

4. Immerse the neck *c d*, of the hollow glass ball *c b*, fig. 9, in water contained in the jar *a a*: then set the jar upon the

pump-plate, and cover it and the ball with the close receiver A. Commence the exhaustion, and as the air goes out of the receiver by its spring, it will also by the same means go out of the hollow ball *e b*, through the neck *d c;* for it will rise up in bubbles to the surface of the water in the jar, whence it will make its way, with the rest of the air in the receiver, through the valves in the barrels to the open air. When the bubbling in the jar is over, the ball is sufficiently exhausted, and then, upon turning the cock *b*, fig. 1, the air will get into the receiver, and press upon the surface of the water in the jar, so as to force the water up into the ball in a jet, through the neck *c d*, and will fill the ball almost full of water. The reason why the ball is not quite filled, is because all the air could not be taken out of it; and the small quantity that was left in, and had expanded itself so as to fill the whole ball, is now condensed into the same state as the outward air, and at the close of the experiment will remain in a small bubble at the top of the ball, where it prevents the water from filling that part.

5. Pour some quicksilver into the jar D, fig. 10, and set it on the pump-plate, near the centre *d*, fig. 1. then set on the tall open receiver EF, so as to cover the jar and hole; and fix upon the receiver the brass plate C. Screw the open glass tube *f g*, which has a brass top on it at *h*, in the syringe H; and putting the tube through a hole in the middle of the plates so as to immerse the lower end *e* of the tube in the quicksilver at D, screw the end *h*, of the syringe, into the plate C. Then draw up the piston in the syringe by the ring I, which will make a vacuum in the syringe below the piston; and as the upper end of the tube opens into the syringe, the air will be dilated in the tube, because part of it, by its spring, gets into the syringe; and the spring of the undilated air in the receiver acting upon the surface of the mercury in the jar, will force part of it up into the tube; for the mercury will follow the piston in the syringe, in the same way, and for the same reason, that water follows the piston of a common pump, when it is raised in the pump barrel. That this effect is not produced by an inexplicable something, called suction, is easily proved: let the air be pumped out of the receiver EF, and then the whole of the mercury in the tube will fall down by its own weight into the jar, and cannot be again raised one hair's breadth in the tube by working the syringe, which shews that what is called suction is inefficient; and to prove that the rising of the mercury is owing to pressure, admit the air into the receiver by the cock *b*, of the air-pump, and its action upon the surface of the mercury in the jar will raise it up into the tube, although

the piston of the syringe continues motionless. If the tube be about 32 or 33 inches high, the quicksilver will rise in it very nearly as high as it stands at that time in the barometer: and if the syringe has a small hole, as at *m*, near the top of it, and the piston be drawn up above that hole, the air will rush through the hole into the syringe and tube, and the mercury will immediately fall down into the jar. If this part of the apparatus be air-tight, the mercury may be pumped up into the tube, to the same height that it stands in the barometer; but it will rise no higher, because the weight of the column in the tube is then the same as the weight of a column of air of the same diameter as the mercury, and reaching from the earth to the top of the atmosphere. In this experiment, and others of the same nature, it is impossible to deny that the mercury is supported in the barometer by the pressure of the atmosphere, and consequently every variation in the state of the atmosphere, must raise the mercury, if it be attended with an increase in density, or sink the mercury, if attended with a diminution of density.

6. It would be needless to multiply experiments, merely for the sake of proving the pressure of the atmosphere; but when a new experiment is attended with something new and pleasing in its exhibition, it is useful for the sake of variety. The following are chiefly introduced with this view. Take a small wooden cup or dish, make a hole in the bottom of it, and fit tightly into this hole the end of a short cylinder of dry willow or hazel wood, as represented by fig. 11. Draw the tubes AB and F out of the receiver EG, fig. 5, and place in the collar of leathers the end of the piece of wood projecting from the bottom of the cup. Pour some mercury into the cup, and exhaust the receiver; the pressure of the external air will then force the mercury through the pores of the hazel or willow, and cause it to descend in a beautiful shower, towards the bottom of the receiver, within which a cup must be placed to receive it, that it may not pass through the hole in the centre of the pump-plate.

7. To the end of a wire or rod that fits the hole in the collar of a receiver EF, fig. 10, fix a piece of dry wood which will easily pass through the same collar. Place the wire in the collar with the wood at its lower end, exhaust the air, and push the wire down so as to immerse the wood in a jar of mercury on the pump-plate. When this has been done, let in the air; and upon taking the wood out of the jar, and splitting it, its pores will be found full of mercury, driven into it, by the force of the air upon being let into the receiver.

8. Place a small receiver O, fig. 1, pl. II, upon the pump plate, and cover it with the large receiver K, through a collar

of leathers in which passes a wire, L. Turn the wire by the ring, P, until its hook takes hold of the little receiver, allowing that receiver to stand with barely its own weight upon the plate. Then, upon working the pump, the air will leave both receivers; but the large one will be forcibly held down upon the plate by the pressure of the external air, whilst the small one O, having no air to press upon it, will continue loose, and may, by means of the wire, be drawn up and let down at pleasure. But, upon letting it quite down to the plate, and admitting the air into the large receiver, the air will press so strongly upon the small receiver O, as to fix it down to the plate; and at the same time, by counterbalancing the outward pressure on the large receiver K, that receiver will become loose.

9. Screw the end R, of the brass pipe RST, fig. 2, upon the pump-plate, and turn the cock G, until the pipe be open; place upon the plate AB, which is soldered on the pipe, the tall receiver IK, which is close at the top: then exhaust the air out of the receiver, and turn the cock G, to prevent its re-entering. Next, unscrew the pipe from the pump, set its end R into a basin of water, and turn the cock G to open the pipe; on which, as there is no air in the receiver, the pressure of the atmosphere on the water in the basin will drive the water forcibly through the pipe, and form a jet in the receiver.

10. The preceding experiments, though they shew that the pressure of the atmosphere is a real agent, do not supply us with a direct proof of the amount of that pressure; but this may be accomplished in the following manner: provide two hemispherical cups, R and S, fig. 3, pl. II, one of which has a ring that enters into the other, which serves as a socket; by this means, when the shoulders, or rims of the hemispheres, are brought together, they admit of no lateral deviation. The surfaces in contact are accurately fitted by grinding them together, so that with the assistance of a little hog's lard or tallow, they are air-tight when closed. Each hemisphere is furnished with a handle, *a d*, but the hemisphere R has also a stop-cock W. The handle *d* screws off, and it then leaves uncovered a perforation which extends into the hemisphere, R, and consequently when R and S are together, the perforation communicates with them both, except when interrupted by the shutting of the stop-cock W. Screw off the handle *d*, put both hemispheres together, and screw R to the pump-plate by the screw which just before fastened the handle *d;* turn the stop-cock W, so that the pipe may be open all the way into the cavity of the hemispheres; then exhaust the air out of them, and shut the stop-cock; unscrew the hemispheres from the pump,

and having replaced the handle *d*, let two strong men endeavour to pull the hemispheres asunder by the rings. They will find the task very hard to perform, and if the instrument were large, they would find it impossible; for even supposing the diameter of the hemispheres to be only four inches, yet it will be found, on suspending weights to one of the rings, that they are pressed together with a force equal to about 180 pounds; for the area of a circle four inches in diameter is 12 square inches, and as the pressure of the atmosphere amounts to 15 pounds upon every square inch, 12 times 15 is 180. To shew that it is the pressure of the air alone that keeps them together, hang them by one of the rings of their handles upon the hook of the wire in the receiver K, fig. 1, (the receiver O being removed,) and the lowermost hemisphere will separate from the other by its own weight, as soon as the air in the receiver is exhausted.

Experiments relative to the Resistance of the Air.

1. The resistance of the air is very clearly proved by the experiment called the two mills. This little machine is represented by fig. 4, pl. II; it consists of two similar but independent axes fixed in a slight frame, in which both may turn with equal freedom. Each axis has four or more thin arms or vanes fixed into it; the vanes are similar in all respects, except in their position; those of the axis *a*, having their planes at right angles to its length, and those of the axis *b* having their planes in an opposite position to the former, that is, parallel with the axis. When the wheel *a* revolves in common air, it is but little resisted, because its vanes cut the air with their thin edges; but the wheel *b* is much resisted, because the broad sides of its sails move against the air when it turns round. In each axis is a pin near the middle of the frame, going through, and standing out a little on each side of it: upon these pins the slider *d* may be made to bear, and so hinder the mill from going, when the strong spring *c*, is set so as to bear against the opposite ends of the pins.

Having set this machine upon the pump-plate under a receiver, with a collar of leathers to admit a wire for pushing down the slider *d*, set the slider against the pins on one side, and the spring *c* upon the opposite ends of the pins; then push down the slider *d*, and the spring acting equally upon each wheel, they will both begin to move with equal velocities, but the wheel *a* will run much longer than the wheel *b*, because the

air exerts much less resistance against the edges of its sails than against the sides of the sails of *b*.

Set the slider and spring against the pins as before; then, having exhausted the receiver, push down the wire to disengage the slider from the pins, and allow the mills to turn round by the impulse of the spring; and as there is no air in the receiver to make any sensible resistance against the wheels, they will both move a considerable time longer than they did in the open air, and they will both be observed to stop together. Hence, it is evident, that the air resists bodies in motion, and that equal bodies meet with different degrees of resistance, according as they present greater or less surfaces to the air in the planes of their motions.

2. Another proof of the resistance of the air is called the guinea and feather experiment. Take a tall receiver L, fig 5, covered at the top with a brass plate, containing a collar of leathers for the reception of a rod *g*. From the under side of the brass plate, suspend, by proper supports, two little shelves which are each furnished with a hinge, to admit of their being turned town from a horizontal to a vertical position. The end of the rod *g* is so formed as just to take hold of both the shelves when they are in a horizontal position; consequently when set to accomplish this, the rod, however little pushed down, will suffer the shelves to become vertical. The shelves being set, a guinea is put upon one of them, and a feather upon the other, and they are caused to fall at the same instant by pushing down the rod *g*, before the exhaustion of the receiver has been commenced; when it will be seen, as all would suppose, that the guinea will reach the bottom before the feather. Replace the shelves with the guinea and feather, exhaust the receiver, and then again let them fall together: they will now descend at an equal rate, and therefore will reach the pump-plate at the same instant. Hence we may conclude, that the only reason why different falling bodies descend with different degrees of velocity, is entirely owing to the resistance of the air, which acts with the greatest force on those bodies which, for their weight, have the greatest bulk. At page 276, vol. 1, this experiment has been alluded to, and its rationale explained.

Experiments relative to the Elasticity of the Air.

1. Tie up a bladder, containing a very small quantity of air, and place it under a receiver. Exhaust the air out of the receiver, and the small quantity which is confined in the bladder, having nothing to act against it, will be so much expanded by its elasticity, as to fill the bladder as full as it could blown of

common air. But upon letting the air into the receiver again, the bladder will shrink into its first dimensions.

2. If a bladder, tied up as for the last experiment, be put into a wooden box, and have twenty or thirty pounds weight of lead put upon it in the box, upon exhausting the air out of a receiver placed over it, the air confined in the bladder will expand itself with a force enabling it to raise up the lead.

3. Take the glass ball, fig. 9, pl. I, as left at the conclusion of the fourth experiment on the atmospheric pressure, that is, full of water, excepting a small bubble of air at the top, with its neck downwards in the jar, *a a*, and covered with a close receiver; exhaust the receiver, and the small bubble of air in the top of the ball will expand itself so as to force all the water out of the ball into the jar.

4. Upon the flat brass plate, AB, fig. 6, pl. II, into which is soldered a pipe EF, furnished with a cock at *w*, place a tall receiver, and screw the pipe by its screw E, upon the air-pump. Open the cock *w*, and exhaust the receiver; then turn the cock to keep out the air, unscrew the pipe from the pump, and screw it into the mouth of the copper vessel CC, fig. 7, which is first about half filled with water. As soon as the cock *w* is re-opened, the elasticity of the air confined in the copper vessel will force the water through the pipe, which terminates at F with a very small aperture, and a jet will thus be formed in the receiver, as perfectly as by the atmospheric pressure on the water in a basin, in the ninth experiment by pressure.

5. If an animal be placed under a receiver, and the air be exhausted, it will soon become convulsed, and, in agony, expire. Experiments of this cruel nature have been tried too often without any useful purpose in view; but they are now so far exploded, as not to be exhibited by any lecturer who would not be thought to libel the feelings of his audience, or reflect discredit on his own. It is enough to be fully aware of the fact, so easily learned, that animal life cannot be supported without the presence of atmospheric air, either at or not very greatly differing from its medium density.

6. Screw the end R, fig. 8, of the pipe RL, upon the pump plate, and turn all the three cocks, D, F, and H, so as to make a communication between all the three pipes, L, Q, and S, by the hollow trunk AB. The plates E and G are made truly flat like a pump-plate, and the ends of the pipes Q and S pass through their centres. Place the receiver I upon the plate G; shut the pipe S by turning the cock H, and exhaust the air out of the receiver I. Then turn the cock D to shut out the air, unscrew the machine from the pump, and having screwed it to the wooden support M, put the receiver K upon the plate E.

This receiver will continue loose on the plate, as long as it remains full of air at its usual density, which will be until the cock H is turned to open the communication between the pipes S and Q, through the trunk AB; and then the air in the receiver K, having nothing to act against its spring, will pass from K into I, until it be so divided between these receivers as to be of equal density in both; after which they will be held down with equal force to the plates by the pressure of the atmosphere, though each receiver will then be kept down with but one half of the pressure upon it that the receiver I had when it was exhausted of air; because it has now one-half of the common air in it which filled the receiver K when it was set upon the plate; and therefore, a force equal to half the force of the spring of common air, will act within the receivers against the whole pressure of the common air upon their outsides.

7. It will be recollected, that a square phial, when exhausted of air, is broken by the atmospheric pressure. Here it may be observed, that the same circumstance will be accomplished by the elasticity of the air contained within the phial, when the external pressure is removed. This may be done by tying or cementing a cork into the phial, and then placing it under a receiver; the air it contains will become active as soon as the receiver is exhausted, and by efforts to expand, the phial will be burst. In this, as in the former case, it is expedient to cover the bottle with a wire cage for the purpose of confining the fragments.

8. If a shrivelled apple be placed under a receiver, and the air be exhausted, the spring of the air in the apple will swell it out till every wrinkle disappear: but upon the admission of the atmospheric pressure, the apple will immediately resume its shrivelled condition.

9. Take a fresh egg, and cut off a little of the shell and film from its smallest end; then put the egg under a receiver, and pump out the air. As soon as the exhaustion is considerably advanced, the contents of the egg will be forced out into the receiver, by the expansion of the small bubble of air contained in the large end, between the shell and film.

10. Put some warm beer into a glass, and having set it on the pump, cover it with a close receiver, and then exhaust the air. Whilst this is doing, and the pressure is more and more taken off from the beer in the glass, the air therein will expand itself, and, rising up in innumerable bubbles to the surface, will thence be taken away with the other air in the receiver. When the receiver is nearly exhausted, the air in the beer, which could not disentangle itself quickly enough to escape with the rest, will now expand itself so that the beer will have

all the appearance of boiling, and the greatest part of it will go over the glass.

11. Put some warm water into a glass, and put a piece of dry wainscot or other wood into the water. Then cover the glass with a close receiver, and exhaust the air; upon which the air in the wood, having liberty to expand itself, will be extricated in abundance, as may be observed by the bubbling of the water about the wood, especially at the ends, because the pores lie lengthwise. A cubic inch of dry wainscot, thus situated, will continue an incessant supply of bubbles for nearly half an hour together.

Miscellaneous Experiments.

1. Screw the syringe H, fig. 10, pl. I, to a piece of lead that weighs one pound at the least; and holding the lead in one hand, pull up the piston in the syringe with the other; then quitting hold of the lead, the air will push it upwards, and drive back the syringe upon the piston. The reason of this is, the vacuum made by drawing up the piston; and the air, which presses every way equally, having nothing to resist its pressure upwards, the lead is thereby pressed upwards contrary to its natural tendency by gravity. If the syringe so loaded be hung in a receiver, and the air be exhausted, the syringe and lead will descend upon the piston rod by their natural gravity; and upon admitting the air into the receiver, they will be driven upwards again, until the piston be at the very bottom of the syringe.

2. Let a large piece of cork be suspended by a thread at one end of a balance, and counterpoised by a leaden weight, suspended in the same manner, at the other. Let this balance be hung to the inside of the top of the large receiver, which being set on the pump, and the air exhausted, the cork will preponderate, and appear to be heavier than the lead; but upon letting in the air again, the equilibrium will be restored. The reason of this is, that since the air is a fluid, and all bodies lose as much of their absolute weight in it as is equal to the weight of their bulk of the fluid, the cork being the larger body, loses more of its absolute weight than the lead, and therefore must in fact be heavier, to balance it under the disadvantage of losing some of its weight: which disadvantage being taken off by removing the air, the bodies then gravitate according to their real quantities of matter, and the cork which balanced the lead in air, shews itself to be heavier when in vacuo.

3. Set a lighted candle upon the pump, and cover it with a tall receiver. If the receiver holds a gallon, the candle will burn a minute; and then, after having gradually decayed from the first instant, it will go out, which shews that a constant supply of fresh air is necessary to support combustion, and it may be observed that no air but what supports combustion will support life. A man renders unfit for breathing as much air in the same time as the candle in this experiment.

The moment when the candle goes out, the smoke will be seen to ascend to the top of the receiver, and there it will form a sort of cloud; but upon exhausting the air, the smoke will fall to the bottom of the receiver, and leave the upper part of this vessel as clear as it was before it was set upon the pump. This shews, that smoke does not ascend because it is devoid of weight, but because it is lighter than air.—See page 276, vol. I.

4. Set a bell upon a cushion on the pump-plate, and cover it with a receiver; then shake the pump, to make the clapper strike against the bell, and the sound will be distinctly heard; but exhaust the receiver of air, and then, however hard the clapper is made to strike against the bell, it will make no sound. This is a proof of the necessity of air to the propagation of sound.

Of the Condensation of Air.

As by lessening the pressure on any particular portion of air, that portion becomes expanded or rarefied; so by increasing the pressure, it takes up less space, or is condensed. The instrument by which this effect is artificially produced, is called a *condensing engine.*

A condensing engine is represented by fig. 9, plate II. WX is a barrel or hollow cylinder, called a condensing syringe; it has a stationary valve opening downwards at the end X; at Q is a handle that works a solid piston; and at W is a hole communicating with the inside of the barrel WX. When the piston is drawn up, a vacuum is formed in the lower part of the barrel, but as soon as the lower part of the piston is raised above the hole W, the air rushes through that hole and fills the barrel; but when the communication with the external air is stopped, by again pushing the piston below the hole, the air in the barrel, as the piston descends, rushes out at the valve near X at the bottom, and passes along a tube contained in the piece F into the receiver L, which is placed upon a plate similar to that of an air-pump. To prevent the condensed air from lifting up

the receiver, the latter is secured by the cross piece D, and the screw nuts KK, which take hold on the strong pillars GG. At every downward stroke of the piston, more air is thrown into the receiver, which, to sustain the elasticity of its contents, is made of very thick glass, strengthened as much as possible by careful annealing. The top of the receiver is covered by a brass cap, in the centre of which is a perforation for a collar of leathers, to admit the wire P, for conducting experiments, like the same contrivance for the exhausted receiver. The air is let out of the receiver by the cock B, which is at the extremity of the tube of communication.

A gauge, RS, is connected with this machine, to indicate the extent to which the condensation in the receiver is carried. It consists of a small glass tube, very strong, and closed at the end S; the other end is connected with the tube leading to the receiver. A small quantity of mercury fills up a part of the cavity about the middle of the tube, and the space between the mercury and the closed end S, is filled with air of the usual density. When therefore the air is condensed in the receiver, and consequently in the tube of communication, the mercury is impelled farther towards S, and the contraction of the space between the mercury and the sealed end of the tube, shews the degree of condensation, as measured by a scale annexed. For example, if the column of air in this space be forced into half the space it occupied at the commencement of the experiment, it is evident that the density of the air is doubled, and the usual expression is, that the receiver contains two atmospheres; if the space be reduced to one-fourth, the receiver is said to contain four atmospheres.

Air-pumps are frequently made, which are contrived so as to be employed either for exhausting or condensing at pleasure. The air-pumps of Smeaton and of Haas are of this description. The object is accomplished by changing the communication between the cylinders and the plate of the pump; for as in those pumps the air is rarefied towards one end, and is condensed towards the other end of each barrel, the machine will exhaust, if the former end of the barrel be made to communicate with the plate of the pump, and the latter with the atmosphere; but it will become a condenser, if the latter end of the barrel be made to communicate with the hole in the centre of the plate, and the former with the atmosphere.

Even the simple air-pump represented by figs. 6 and 7, pl. I, may be used as a condenser. For example, place the head or handle KI, in the direction L *o*, pull up the piston, and the

external air will rush into the cylinder G; turn the handle KI into the position IK, thrust down the piston, and the air will be forced out of the cylinder into the receiver standing on the pump-plate. Put the handle into its former position, pull up the piston, and proceed as before, till the required degree of condensation is obtained. It is obviously necéssary here, as in the former engine, to have the receiver secured by two upright pieces screwed into the board, as at OO, and a cross-piece fastened by screws.

When great degrees of condensation are required, iron, brass, or other tough metallic vessels, are the most suitable for receivers, and the figure which will sustain the greatest force is that of a globe.

Condensed air may be applied to give motion in a great variety of instances, and may be rendered an agent of prodigious power, as may be instanced in the air-gun. The condensing syringe WX, fig. 9, pl. II, is screwed over a hole in a hollow metallic globe, containing a valve opening inwards, and is employed to condense the air in the globe to the amount of ten or twelve atmospheres. When thus filled, the globe is screwed upon a machine usually made in the form of a common gun. If the valve of the globe were open, the whole is so contrived that the condensed air would rush upon the bullet, and drive it violently out of the barrel. The office of the lock is therefore, according to the size of the globe, to open the valve only so far as may be requisite to let out, at one stroke, sufficient air to impel a single bullet, the remainder being reserved for the repetition of the experiment.

Pneumatical Experiments by Condensation.

A great variety of experiments may be performed by condensation, to a few of which we shall advert.

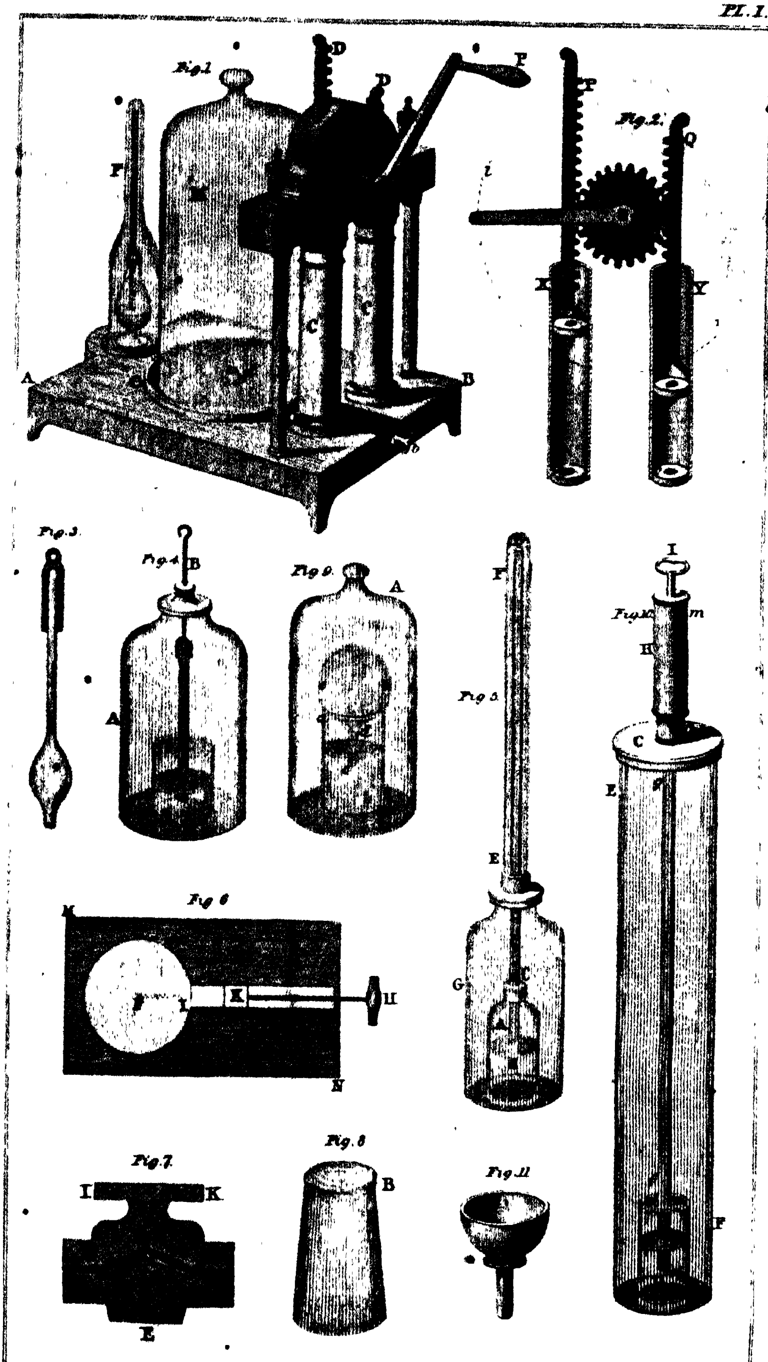
1. The sound of a bell, or any other noise, is much louder in condensed than in common air.

2. If a square phial be selected, which is found to bear the pressure of the common atmosphere, when exhausted of air; it may be broken by condensing the air round it.

3. A fountain may be made by condensed as well as by rarefied air. For this purpose, procure a strong copper vessel, as represented by fig. 11, having a tube that screws into its neck, so as to be air-tight, and long enough to reach nearly to the bottom. Having poured a quantity of water into the vessel, but not enough to fill it, and screwed in the tube, adapt it to a condensing syringe, and condense the air in the vessel; shut the stop-cock, and unscrew the syringe, then, on opening

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Pl. 1.



Engraved by Jas. Davis

the stop-cock, the air acting upon the water in the vessel, will force it out into a jet of considerable height. Variety may be given to the experiment, by screwing alternately upon the tube pieces which contain minute apertures differently disposed.

4. Fig. 10, represents an instrument nearly like the condensing syringe, but it has no hole in the upper part, nor any valve at the bottom. It has a solid piston, and the handle G is a globe. This instrument answers the purpose of a tinder-box; for, upon striking the handle G with palm of the hand, the air below the piston is condensed, and the act of condensing air always eliciting caloric, the quantity is in this instance sufficient to light a piece of tinder fastened by a little hook to the bottom of the piston, and therefore by drawing out the piston, immediately after the stroke, a match may be lighted in the usual manner. The cylinder ought to be at least eight inches long, and its bore about three-quarters of an inch. The tinder is prepared from agaric, which is first boiled in water; beaten well when dry; steeped in a solution of salt-petre; and lastly, dried in an oven. If the solution of nitre be too strong, the agaric will not so easily inflame.

Of Pneumatical Instruments for meteorological purposes.

The common Barometer.

Ever since it was observed, that the height of a column of mercury, sustained in a tube by the pressure of the atmosphere, varied in height, at different times, and that these variations were accompanied or followed by changes in the weather, such an instrument has been applied to meteorological purposes, under the name of the *barometer*.

Barometers have been constructed in a variety of ways, many of which are more expensive, but none of them superior, in real utility, to the common form, represented by fig. 1, pl. III. It consists of a glass tube, about 34 inches in length, and one-third of an inch in diameter. The upper end, A, of this tube is hermetically sealed.* It is filled with purified mercury, and

* By the expression "hermetically sealed," is meant the closing of a tube, &c. by the consolidation of its own substance. The glass is heated in the fire, or with the assistance of a blowpipe at a lamp, till it is partially fused, the end is then drawn out and twisted round till the aperture is perfectly closed. The twisting is essential; a tube drawn out in a straight line will always be a tube.

the open end, B, is inserted into a basin containing the same metal. The tube and basin are fixed to a frame of wood, and suspended in a vertical situation; and the tube, from B to F, is generally covered with wood, to prevent the breaking of it by accident; from F to A is mostly covered with plain glass, set in a frame, and opening like a door.

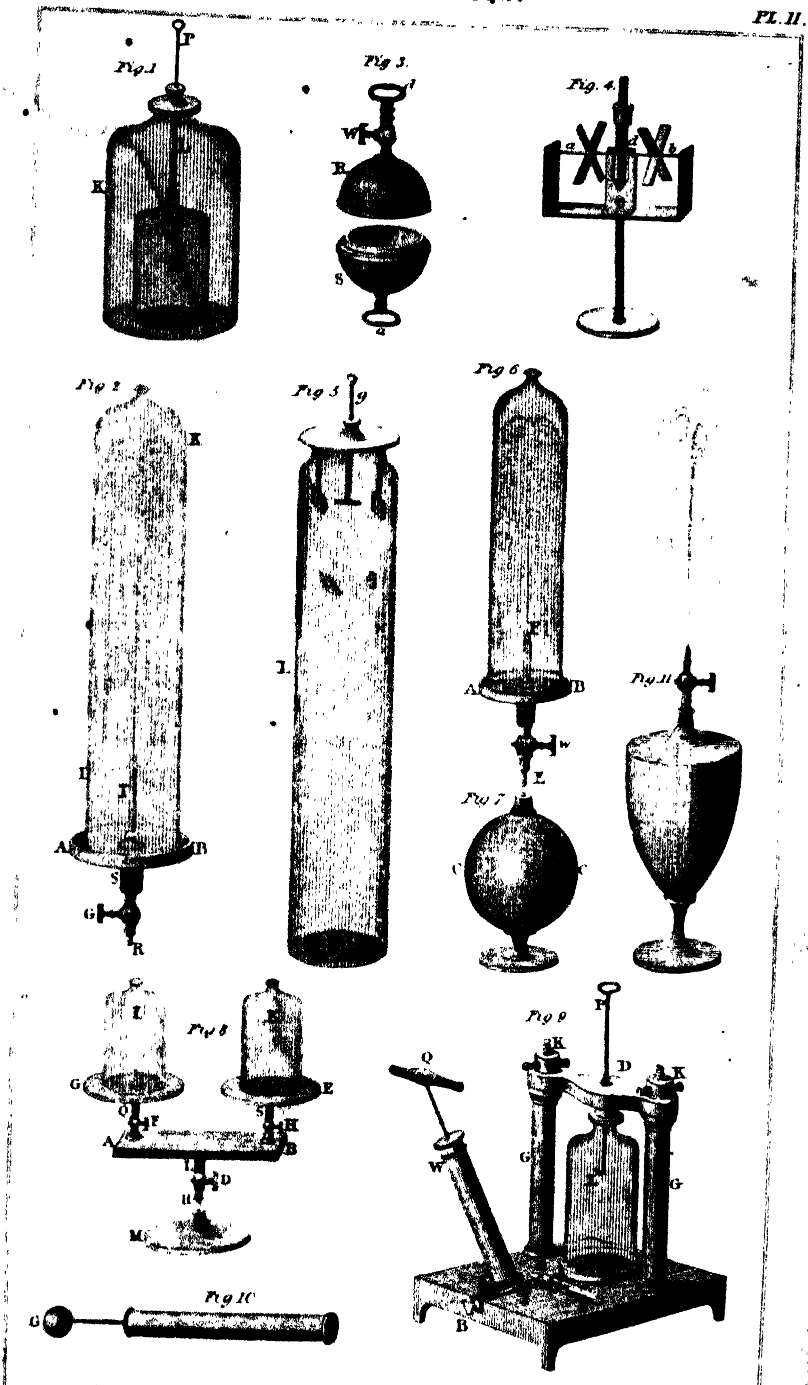
The mercury, in the barometer tube, will subside, till the column be equivalent to the weight of the external air upon the surface of the mercury in the basin, and it therefore becomes a measure of that weight. In this kingdom, the extremes of the fluctuation are almost invariably found between 28 and 31 inches, so that the range may be considered as never exceeding three inches, and it seldom exceeds two inches and a half in any one year.

The height of the mercury in the tube, above the surface of the mercury in the basin, is called the standard altitude; and the difference between the greatest and least altitudes, is called the scale of variation.

The scale of variation attached to the upper part of a barometer, is shewn more at large by fig. 2, pl. III. The measurement of the inches is taken from the surface of the mercury in the basin; but as the mercury cannot rise in the tube without sinking in the basin, or *vice versâ*, it is obviously correct for only one state of the atmosphere. For ordinary purposes, however, no allowance is made for this source of imperfection. The scale of variation is furnished with an instrument called a vernier or nonius, *g h*, which is an addition of more value and greater ingenuity than might at first sight be supposed. If each inch of the scale of variation, LM, fig. 2, be divided into ten equal parts, marked with 1, 2, 3, &c. increasing upwards, and a nonius, or small scale, *g h*, whose length is eleven-tenths of an inch, be divided into ten equal parts, marked with 1, 2, 3, &c. increasing downwards, and so placed as to slide along the scale of variation, the altitude of the mercury in the tube above the surface of that in the basin, may easily be found in inches and the hundredth parts of an inch: for if the surface of the mercury in the tube does not coincide with a division in the scale of variation, place the index, *l*, of the nonius even with the surface, and observing where a division of the nonius coincides with one in the scale, the figure in the nonius will shew what hundredth parts of an inch are to be added to the tenths immediately below the index. Let, for instance, the surface of the mercury be between 7 and 8 tenths above 30 inches, and the index of the nonius being placed even with it, and the figure 5 upon the nonius being observed to coincide with a division upon the

PNEUMATICS.

Pl. II.



scale, the altitude of the barometer will be 30 inches and $\frac{7}{10}$ths of an inch; for each division of the nonius being greater than that of the scale by $\frac{1}{100}$th of an inch, and there being five divisions, the whole must be $\frac{5}{100}$ths of an inch above the number seven in the scale, and the height of the mercury is therefore 30.75. A meaner use than this is often made of a nonius, as it is commonly supposed to have no other purpose to serve, than the single one of setting its index to the height of the mercury, at any particular observation, as a memorandum of the height at that time.

The tubes of which barometers are made should have a bore of not less than one-third of an inch in diameter, and they should be perfectly clean within. To prevent their contracting any dirt before they are used, it is usual to seal hermetically both their ends at the glass-house; when a tube is obtained in this state, one of its ends, on preparing it for a barometer, will be to cut off, which is easily done by marking it across with a file, and then applying to the scratch the edge of a piece of iron just red-hot, by which any length desired will instantly be severed from the rest of the tube.

Mercury in a state of great purity, is very essential to a good barometer. It is generally purified by distillation; but as this operation may not be convenient to some, we shall mention Dr. Priestley's mode of purifying it, which is remarkable for its simplicity, and has an excellent effect: Let a strong 10 or 12 ounce phial, with a ground stopper, be a quarter filled with the mercury to be purified; put in the stopper, hold the bottle inverted with both hands, and shake it violently, by striking the hand that supports it against the knee. After twenty or thirty strokes, take out the stopper, and blow into the phial with a pair of bellows, to change the air. If the mercury is not pure, the surface will become black in a short time, and if very foul, the black coat will appear coagulated. Invert the phial, stopping it with the finger, and let out the running mercury. Put the coagulated part into a cup by itself, and press it repeatedly with the finger, so as to get out the mercury entangled in it. Put both portions of mercury into the phial again, and repeat the process till no more black powder separates.

After the mercury has been thus purified from its admixture with baser metals, it should be boiled for about half an hour, to free it from the moisture which it is apt to contain. It may then, when nearly cool, be poured into the tube, (which must be perfectly dry, well cleaned, and rather warm,) till it reaches to within two inches of the top; then, to free it from any air which may have become entangled in it while filling,

hold it, with the sealed end lowest, in an inclined position, over a chafing-dish of burning charcoal, placed near the edge of a table, in order that all parts of the tube may be exposed successively to the action of the fire, by moving it obliquely over the chafing-dish. The sealed end is to be first gradually presented to the fire, and the other parts in slow succession. The air, if any be contained in the tube along with the mercury, will by this means be expanded, and rising to the top of the tube, will escape. The tube must now be filled to the brim, the open end must then be stopped with the finger, which must be held upon it till that end is plunged into a basin of mercury. The finger must then be taken away, and the tube being held vertically, the mercury in it will remain suspended at the height of 29 or 30 inches, or whatever balances the pressure of the atmosphere at the time. The space at the top of the tube may be considered a perfect vacuum at the first construction of the barometer, but in the course of time, subtile vapours, that could not be extricated from the mercury, rise up into it, though in very small quantity; and even minute portions of the mercury itself are apt to become volatilized at common temperatures.

The Diagonal Barometer.

The utmost range of the mercury, in a common barometer, being only three inches, the attempted improvements of the instrument have generally had for their object, the enlargement of this scale.

The simplest mode of effecting this purpose, is perhaps exemplified in the diagonal barometer, which is represented at fig. 3, pl. III. The tube, KLM, is sealed at the end M; it is perpendicular from K to L, but at L it is bent into the diagonal LM. The scale of variation begins at L, and the extent of it, by this arrangement, is increased in the proportion of the distance QM to that of QL. Had the tube been straight, Q would have been the limit of the scale of variation, but as it is bent, and it is the perpendicular height which regulates the variations of the mercury; to gain the perpendicular height of Q from L, in the diagonal tube, the mercury must traverse the space LM.

Experience, however, has evinced, that though the tube of the diagonal barometer may be so much bent towards a right angle, as to treble or quadruple the extent of the scale of variation, yet the consequences are the deformity of the instrument, and the uncertainty of its indications. The freedom of

motion in the mercury is obstructed by the angle it has to turn, and by the attraction of cohesion between the mercury and the glass, along the lower side of each of these substances in the diagonal part LM. This attraction increases with the obliquity; and when the angle QLM exceeds 45°, the instrument becomes useless by the separation of globules of mercury from the column.

The Wheel Barometer.

Most of the various contrivances which have been adopted to increase the barometrical range, are deservedly becoming obsolete; but the wheel barometer still maintains its ground, perhaps for no other reason than that of its rather elegant appearance. The internal part of it is represented by fig. 4, pl. III. The principal glass tube, AB, has a globular head at A, and is bent upwards at the lower end B. Upon the surface of the mercury, in the recurved leg, there is placed a short glass tube loaded with mercury; to this loaded tube is attached a hair or fine silken thread, which passes over a small pulley, and has a weight at the other end of it, to balance the former. As the surface of the mercury in the globe A is very large, and that at B very small, the motion of mercury in the recurved leg, and consequently of the weight reposing in it, will be very considerable; and as the little ball rises and falls with the mercury, the thread turns the pulley, and consequently will turn an index upon its axis. The index and general figure of the instrument in front, is shewn by fig. 5. A is the index, on the axis of the pulley behind it. BC is the circle or face graduated so as to shew the height of the mercury in inches and tenths. The face is silvered or enamelled like that of a clock, and a spirit level G is often added at the bottom, to ascertain when the column of mercury is vertical. A second index, H, which has no connection with the pulley, is used to place over the index A, to shew the deviation of A from the place it had at any particular time of observation. The axis of the index H comes through a hole in the glass covering the face BC, and is turned by a small milled head. In the upper part of the frame is a thermometer and hygrometer, which instruments will be noticed afterwards.

By means of the wheel barometer, a very extensive scale of variation is obtained; but in this instrument, the friction of the several parts, however accurately and delicately they may be made, are considerable deductions from its value.

The Portable Barometer.

The common portable barometer has a little bag, made of a piece of bladder, for the purpose of containing the mercury instead of a basin. No part of the mercury is exposed to the atmosphere; but the atmosphere presses upon the outside of the bag, and thus produces the same effect. To render the instrument perfectly portable in its frame, a screw, or some other contrivance to compress the bag, is used to force the mercury to the top of the tube, and it may then be moved with freedom.

Portable barometers are chiefly required for measuring the heights of mountains, and they should always be constructed in the most accurate manner; the mercury in the cistern must be raised always to the same mark or distance from the scale, in order that the divisions of the scale may indicate the real altitude of the surface of the mercury in the tube above that of the mercury in the cistern. They should also be furnished with a stand, capable of supporting them in a vertical position, on the side of a mountain, or any other situation. Jesse Ramsden, an eminent philosophical instrument-maker, contrived a valuable barometer of this sort, and has described it himself in the Philosophical Transactions. The principal parts of it are a simple, straight tube, fixed into a wooden cistern A, (fig. 6, pl. III,) which, for the convenience of carrying, is shut with an ivory screw B, and that being removed, is open when in use. Fronting this aperture, is distinctly seen the coincidence of the gauge mark, with a line on the rod of an ivory float, swimming on the surface of the quicksilver, which is raised or depressed by a brass screw, C, at the bottom of the cistern. From this, as a fixed point, the height of the column is readily measured on the scale D attached to the frame, always to $\frac{1}{500}$th of an inch, by means of the nonius E, moved with rack-work. A thermometer, F, is placed near the cistern, the ball of which is not enclosed within the wood-work, but left projecting. The three-legged stand, supporting the instrument when in use, serves as a case for it when inverted, and carried in the state shewn by fig. 7, from place to place. Two of these barometers, made by the Inventor, after the mercury in them had been carefully boiled, being suffered to remain long enough in the same situation, to acquire the same temperature, usually agreed in height, or rarely differed from each other more than a few thousandth parts of an inch.

The Thermometer.

The thermometer is a chemical rather than a pneumatical instrument, but it claims notice in this place as a useful appendage to the barometer. All substances expanding with an increase of their temperature, it is obvious that, under the same pressure of the atmosphere, the mercury in the barometer will be highest when the heat is greatest; a correction is therefore necessary for this source of error, before the exact effect of the pressure can be ascertained, and this is accomplished by means of the thermometer, or instrument for measuring the degrees of heat, joined with a knowledge of the rate at which the mercury in the barometer expands. Mercury expands nearly in the exact proportion of the degrees of heat; its expansion for every degree of heat, from 32° upwards, or the contraction for every degree of heat from 32° downwards, is equal to 0.000102 of the whole bulk, which at 32° is called one, or unity; the rule, however, deducible from this observation is not directly applicable to the barometer, because the glass tube does not expand in the same proportion as the mercury, and because the Torricellian vacuum cannot at all temperatures be considered perfect. General Roy, therefore, undertook to determine the actual increase of the altitude of the mercury, arising from an increase of temperature, by experiments on the barometer itself. When the mercury stood at 30 inches, he exposed a barometer to different degrees of heat, in an apparatus admitting the whole column to be rendered of the same uniform temperature; and measured the increase or decrease of altitude which was occasioned by the various degrees of heat. The result of his experiments is contained in the annexed table:

Thermometrical degree of heat to which the barometer was exposed.	Altitude of the mercurial column.	Differences of the expansions.
212°	30.5117	0.0229
202	30.4888	0.0236
192	30.4652	0.0243
182	30.4409	0.0250
172	30.4159	0.0257
162	30.3902	0.0264
152	30.3638	0.0271
142	30.3367	0.0277
132	30.3090	0.0283
122	30.2807	0.0289
112	30.2518	0.0295

Table for the correction of the expansion of the mercurial column by heat.

Thermometrical degree of heat to which the barometer was exposed.	Altitude of the mercurial column.	Differences of the expansions.
102°	30.2223	0.0301
92	30.1922	0.0307
82	30.1615	0.0313
72	30.1302	0.0318
62	30.0984	0.0323
52	30.0661	0.0328
42	30.0333	0.0333
32	30.0000	0.0338
22	29.9662	0.0343
12	29.9319	0.0348
2	29.8971	0.0070
0	29.8901	

In order to apply the correction for expansion, we must find, by means of this table, what the column of mercury would be, if the mercury of the barometer had been at 32°, instead of its actual temperature. For this purpose, the actual temperature of the mercury, which is ascertained by means of the thermometer, must be found out in the first column of the table, and opposite to it is the expansion for a column of 30 inches, or its bulk at that temperature. Then say, as this bulk is to thirty inches, so is the observed altitude of the mercury in the barometer, to a fourth proportional, which is the corrected altitude. Thus if the observed altitude be 28 inches, and the temperature of the mercury be 72°, in the table, 30.1302 will be found opposite 72°; therefore say, as 30.1302: 30 :: 28 : to a fourth proportional, which is 27.879 inches; so that, had the temperature of the mercury in the barometer been 32°, the observed barometrical altitude would not have been 28, but 27.879 inches. When the degree of temperature is not mentioned in the table, the calculation may nevertheless be made by taking a proportional part of the difference of the two expansions at the degrees of temperature between which the degree in question is contained, and adding such proportional part to the lower number.

For the method of constructing the thermometer, and the various kinds of this instrument, see page 317 of the present volume.

The Hygrometer.

The state of the atmosphere, with respect to dryness or moisture, is measured by an instrument called an *hygrometer*, or *hygroscope.*

Various substances are susceptible of considerable alterations in weight or length, by attracting or parting with moisture; such substances are called *hygroscopic*, and some of those which have been found the most sensible and regular in their alterations have been selected for philosophical purposes.

The twisted fibres of wild oats, a sea-weed, salted strings, pieces of deal cut across the grain, pieces of cat-gut, &c. have all been tried, and had their share of admirers as hygrometers, but these substances are not much to be depended on, their power of absorbing water being too liable to fits of increase and decrease, and sometimes so nearly ceasing as to be useless. The effect of humidity is not always to increase the length of the hygroscopic body: for example, water, by introducing itself within cords, makes the fibres twist and become situated obliquely, and therefore produces between those fibres such a separation, as causes the cord to thicken or swell, and, by a necessary consequence, to shorten. The twisted threads of which cloths are fabricated, may be considered as small cords, which experience, in like manner, a contraction by the absorption of moisture; and therefore cloths, especially when wetted for the first time, contract in the two directions of their intersecting threads; paper, on the contrary, which is only an assemblage of filaments, very thin, very short, and disposed irregularly in all directions, lengthens in all the dimensions of its surface, in proportion as the water, by insinuating itself between the intervals of those filaments, acts by placing them further asunder, proceeding from the middle towards the edges.

De Luc and De Saussure have investigated the subject of hygrometers with great attention and ability, and each of these philosophers has selected, as the result of his inquiries, a different substance to form the instrument under notice. The principal piece in Saussure's hygrometer is a hair, which is submitted to a peculiar preparation, the design of which is to divest it of a kind of oiliness natural to it, and to secure it, in a certain degree, from the action of humidity. This preparation is made at the same time upon a certain number of hairs forming a tuft, the thickness of which need not exceed that of a writing-pen, and contained in a fine cloth serving them for a case. The hairs thus enveloped are immersed in a long-necked phial full of water, which holds in solution nearly a hundredth

part of its weight of sulphate of soda, making this water boil nearly thirty minutes; the hairs are then passed through two vessels of pure water while they are boiling, afterwards they are drawn from their wrapper and separated; then they are suspended to dry in the air, after which there only remains to make choice of those which are the cleanest, softest, most brilliant, and most transparent. It is known that humidity lengthens the hair, and that the process of drying shortens it. To render both these effects more perceptible, Saussure attached one of the ends of the hair to a fixed point, and the other to the circumference of a moveable cylinder, that carries at one of its extremities a light index or hand. The hair is bound by a counterweight of about three grains, suspended by a delicate thread of silk, which is rolled in a contrary way about the same cylinder. In proportion as the hair lengthens or shortens, it causes the cylinder to turn in one of the other direction, and by a necessary consequence, the little index turns likewise, the motions of which are measured on the circumference of a graduated circle, about which the index performs its revolution as in the wheel barometer. In this manner very minute variations in the length of the hair become perceptible. To give to the scale such a basis as may establish a relation between all the hygrometers that are constructed upon the same principles, Saussure assumes two fixed terms, one of which is the extreme of humidity, and the other that of dryness: he determined the first by placing the hygrometer under a glass receiver, the whole interior surface of which he had previously moistened with water; the air being saturated by this water, acts by its humidity upon the hair to lengthen it. He repeated the moistening of the interior of the receiver, as often as it was necessary, and he knew that the term of extreme humidity was attained, when, by a longer continuance under the receiver, the hair ceased to extend itself. To obtain the contrary limit of extreme dryness, the same philosopher made use of a hot and well-dried receiver, under which he included the hygrometer, with a piece of iron plate, likewise heated and covered with a fixed alkali. This salt, by absorbing the humidity remaining in the air, causes the hair to contract itself, until it has attained the ultimate limit of its contraction. The scale of the instrument is divided into a hundred degrees; the zero (0) indicating the limit of extreme dryness, the number 100 that of extreme humidity.

The effects of moisture and of dryness upon the hair are sometimes increased and sometimes diminished by those of heat; so that, if it be supposed, for example, that the air is heated about the hygrometer, on one part, this air, whose dis-

solving power with regard to the water will be augmented, will take away from the hair a portion of the water which it had imbibed, thus tending to shorten the hair; while, on the other part, the heat, by penetrating it, will tend, though much more feebly, to lengthen it, and hence the total effect will be found to consist of two partial and contrary effects, the one hygrometric, the other pyrometric. In observations, therefore, which require the greatest precision, it is necessary to consult the thermometer at the same time with the hygrometer; and on this account, Saussure has constructed from observation, a table of correction, by which the action of humidity may be separated from that of heat.

De Luc employs, for the construction of his hygrometers, a very thin slip of whalebone cut across the grain; one of his instruments is represented by fig. 8, pl. III, and he thus describes them in his paper in the Philosophical Transactions, vol. 81: "Their frame will be sufficiently known from the figure; therefore I shall confine myself to the description of some particulars. The slip of whalebone is represented by *a b*, and at its end *a* is seen a sort of pincers, made only of a flattened bent wire, tapering in the part that holds the slip, and pressed by a sliding ring. The end *b* is fixed to a moveable bar *c*, which is moved by a screw for adjusting at first the index. The end *a* of the slip is hooked to a thin brass wire, to the other end of which is also hooked a very thin silver-gilt lamina, that has at that end pincers similar to those of the slip, and which is fixed by the other end to the axis, by a pin in a proper hole. The spring, *d*, by which the slip is stretched, is made of silver-gilt wire; it acts on the slip as a weight of about 12 grains, and with this advantage over a weight (besides avoiding some other inconveniences) that, in proportion as the slip is weakened in its lengthening, by the penetration of moisture, the spring, by unbending at the same time, loses a part of its power. The axis has very small pivots, the shoulders of which are prevented from coming against the frame, by the ends being confined, though freely, between the flat bearings of the heads of two screws, the front one of which is seen near *f*. The section of that axis, of the size that belongs to a slip of about eight inches, is represented by fig. 9; the slip acts on the diameter *a a*, and the spring on the smaller diameter *b b*." These instruments are commonly made from two to three times the size of the figure.

When the sensibility of this hygrometer has become impaired by long exposure, it may be in some measure restored, by placing the instrument in water, and gently cleaning the whalebone slip by means of a hair-pencil.

An hygrometer is usually added to the upper part of the wheel-barometer, as shewn at V, fig. 5, pl. III; and in the same instrument, a thermometer, W, generally occupies the middle part.

Observations on the hygrometer have not been so long and so diligently registered with observations on other instruments regarding the weather, as appears desirable: too much reliance has been placed on the exclusive indications of the barometer and thermometer, and farmers and agriculturists, to whom just prognostications of the temporary changes in the weather are so important, scarcely know the use of other instruments. After 20 years' experience in the use of hygrometers, De Luc has formed some important deductions, from which we shall make an extract: "From those determinations in hygrometry, some great points are already attained in hygrology, meteorology, and chemistry, of which I shall only indicate the most important:

"1st. In the phenomena of *dew*, the grass often begins to be *wet*, when the *air* a little above it is still in a middle state of *moisture;* and *extreme moisture* is only certain in that *air*, when every solid exposed to it is *wet*.

"2dly. The *maximum of evaporation*, in a close space, is far from identical with the *maximum of moisture;* this depending considerably, though with the constant existence of the other, on the *temperature* common to the *space* and to the water that evaporates.

"3dly. The case of *extreme moisture* existing in the open, transparent air, in the day, even in the time of *rain*, is extremely rare: I have observed it only once, the temperature being 39°.

"4thly. The *air* is *dryer* and *dryer*, as we ascend in the atmosphere; so that in the upper attainable regions, it is constantly very dry, except in the *clouds*. This is a fact certified by De Saussure's observations and mine.

"5thly. If the whole atmosphere passed from *extreme dryness* to *extreme moisture*, the quantity of *water* thus *evaporated* would not raise the *barometer* as much as half an inch.

6thly. In chemical operations on *airs*, the greatest quantity *of evaporated water* that may be supposed in them, at the common *temperature* of the atmosphere, even if they were at *extreme moisture*, is not so much as $\frac{1}{100}$th part of their mass. These two last very important propositions have been demonstrated by De Saussure.

The Rain-Gauge.

The quantity of water returned by the atmosphere to the earth in the state of rain, is ascertained by an instrument called a *pluviometer* or *rain-gauge.*

The rain-gauge is usually made in the form shewn at fig. 10, pl. III. Its general form is that of a jar, or hollow cylinder, with a funnel on the top of it. It is made of copper, or tinned iron plates, japanned within and without. The upper part of the funnel has an edge of brass, which is cylindrical, with its sides perpendicular to the horizon. The rain falling within this cylindrical brass edging, passes from the sides of the funnel through the aperture N, into the receiver ABCD, from which it cannot evaporate sensibly during the short intervals that usually elapse between different observations. Across the cylindrical edge of the funnel, is fixed a bar M, in the centre of which is a socket *g*, of nearly equal width to the aperture N at the bottom of the funnel, both being made to admit the measuring rod, R; but the aperture N is the wider of the two, and fits the rod but loosely, to allow an adequate passage for the rain. To the bottom of the measuring rod, is attached a floating-piece Q, made hollow, of tinned plates japanned. When the floating-piece, Q, is placed on the bottom of the vessel ABCD, and the funnel over it, the top of the rod is exactly even with the top of the socket *g*, and therefore, on the apparatus being placed in an open situation, the rain received into the vessel will raise the float, and the rod is graduated so that the divisions shew, in inches and tenths of an inch, the depth of rain which has fallen on a space equal in area to the cylindrical ring which surmounts the funnel. It is therefore evident, than when the ring and the receiver have the same interior diameter, the rod must be divided exactly into inches and tenths; but in proportion as the receiver has a smaller diameter than the ring, the divisions of the rod must be greater than inches and tenths. When an observation has been taken, the contents of the receiver must be let off, which is most conveniently done by a cock at the bottom.

Rain-gauges are made of various sizes, but if the ring be less than eight inches in diameter, it may be considered too small, and in general, twelve inches may be considered not unnecessarily large.

A very simple rain-gauge may be easily constructed by placing a funnel in a bottle. Supposing the area of the funnel to be exactly ten square inches, the quantity of rain caught may be ascertained by multiplying the weight in ounces by .173, which gives the depth in inches, and parts of an inch.

A rain-gauge should always be fixed where the rain has free access to it; no wall or other shelter in the neighbourhood should be above it. Hence the tops of buildings are the most suitable places. When observations taken with a rain-gauge at one place, are compared with those of another, the instruments should be at the same height above the ground; as, even at the same place, the quantities of rain caught at different elevations will be different.

The Anemometer, or *Wind-Gauge*.

In keeping a journal of the weather, the two particulars to be noted respecting the wind, are, its direction, and its velocity or strength. These particulars are commonly obtained by the use of separate instruments, of which those for the former purpose, or the direction of the wind, are too familiar to all under the name of wind-vanes, weather-cocks, &c. to require any further notice in this place; but to ascertain the velocity or strength of the wind, a considerable diversity of contrivances has appeared, many of which display no inconsiderable share of ingenuity. It has been proposed to suspend a rod, in the manner of a pendulum, with a flat board instead of a ball at its lower extremity. It is obvious, that when the wind impinges upon such a board, it will, according to its strength, force it more or less out of a vertical position, and therefore the quantity of the angle of deviation will be the measure of that strength. Another contrivance resembles a small windmill, by the number of the revolutions of which, in a given time, the result desired may be obtained. Instruments have even been described, which express upon paper, not only the sveeral winds that have blown during the space of twenty-four hours, but at what hour they began and ended, with the strength and velocity of each. These contrivances have, however, some defects or inconveniences, which render them inferior to the anemometer invented by Dr. James Lind, of Windsor, and of which we subjoin the inventor's description from the 65th volume of the Philosophical Transactions.

"This simple instrument (represented by fig. 11, pl. III) consists of two glass tubes, AB, CD, of five or six inches in length.* Their bores, which are so much the better always for being equal, are each about $\frac{4}{10}$ths of an inch in diameter. They are connected together like a syphon, by a small bent

"* They ought to be longer, as in several cases the above-mentioned length has been found insufficient.

tube *a b*, the bore of which is $\frac{1}{10}$th of an inch in diameter. On the upper end of the leg AB, there is a tube of latten brass, which is kneed or bent perpendicularly outwards, and has its mouth open towards F. On the other leg CD is a cover, with a round hole G in the upper part of it, $\frac{2}{10}$ths of an inch in diameter. This cover, and the kneed tube, are connected together by a slip of brass *c d*, which not only gives strength to the whole instrument, but also serves to hold the scale HI. The kneed tube and cover are fixed on with hard cement, or sealing-wax. To the same tube is soldered a piece of brass *e*, with a round hole in it, to receive the steel spindle KL, and at *f* there is just such another piece of brass soldered to the brass hoop *g h*, which surrounds both legs of the instrument. There is a small shoulder on the spindle at *f*, upon which the instrument rests, and a small nut at *i*, to prevent it from being blown off the spindle by the wind. The whole instrument is easily turned round upon the spindle by the wind, so as always to present the mouth of the kneed tube towards it. The lower end of the spindle has a screw on it, by which it may be screwed into the top of a post, or a stand made on purpose. It also has a hole at L, to admit a small lever for screwing it into wood with more readiness and facility. A thin plate of brass, *k*, is soldered to the kneed tube about half an inch above the round hole G, so as to prevent rain from falling into it. There is likewise a crooked tube AB, fig. 12, to be put occasionally upon the mouth of the kneed tube F, in order to prevent rain from being blown into the mouth of the wind-gauge, when it is left out all night, or exposed in the time of rain. The force or momentum of the wind may be ascertained by the assistance of this instrument, by filling the tubes half full of water, and pushing the scale a little up or down till the 0 of the scale, when the instrument is held up perpendicularly, be on a line with the surface of the water, in both legs of the wind-gauge. The instrument being thus adjusted, hold it up perpendicularly, and turning the mouth of the kneed tube towards the wind, observe how much the water is depressed by it in one leg, and how much it is raised in the other. The sum of the two is the height of a column of water which the wind is capable of sustaining at that time; and every body that is opposed to that wind, will be pressed upon by a force equal to the weight of a column of water, having its base equal to the surface that is exposed, and its height equal to the altitude of the column of water sustained by the wind in the wind-gauge. Hence the force of the wind upon any body where the surface opposed to it is known, may be easily found, and a ready comparison may be made betwixt the strength of one

gale of wind and that of another, by knowing the heights of the columns of water, which the different winds were capable of sustaining. The heights of the columns in each leg will be equal, provided the legs are of equal bores; otherwise the heights must be calculated accordingly.

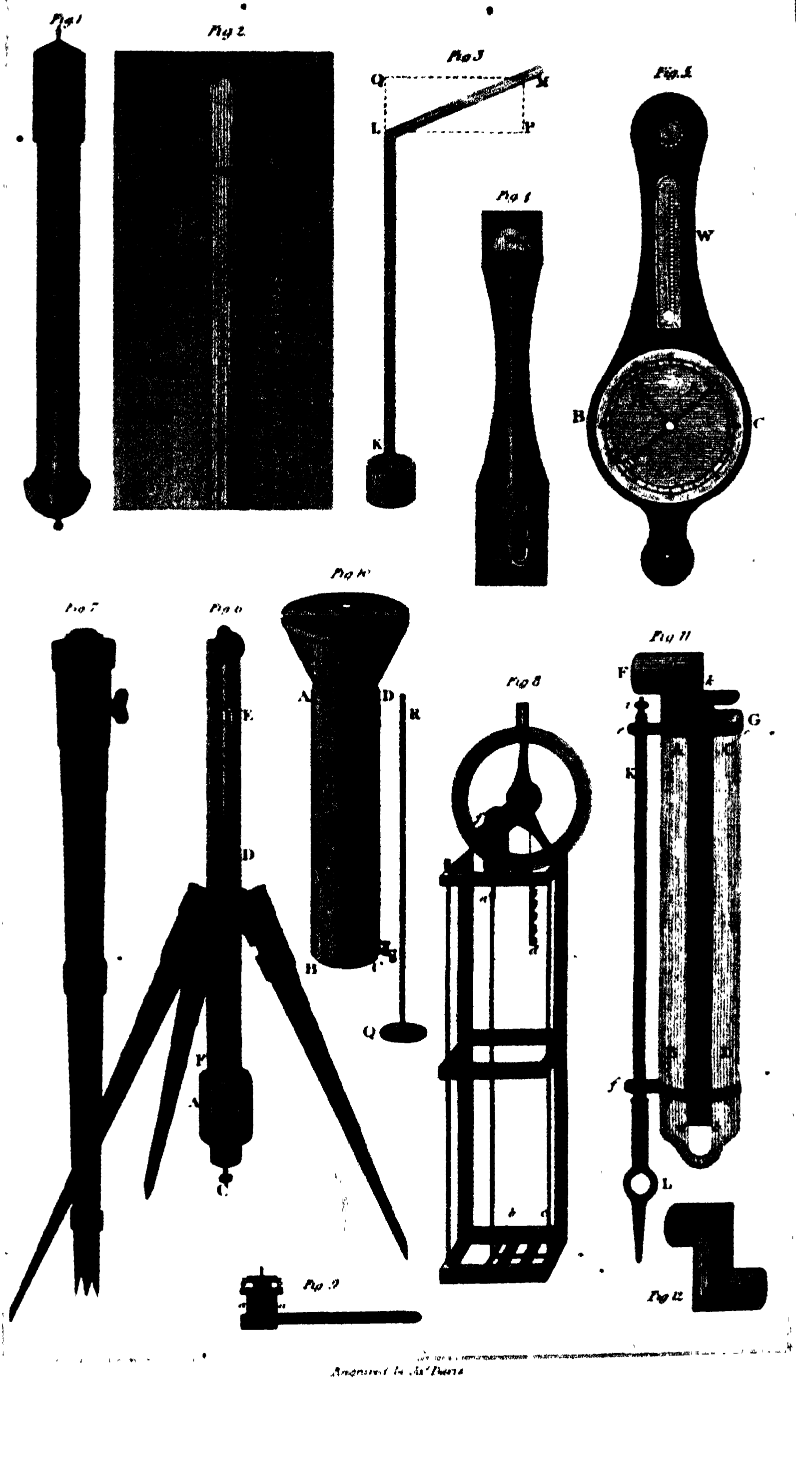
"The force of the wind may likewise be measured with this instrument, by filling it until the water runs out at the hole G. For if we then hold it up to the wind as before, a quantity of water will be blown out; and, if both legs of the instrument are of the same bore, the height of the column sustained will be equal to double the column of water in either leg, or the sum of what is wanting in both legs. But if the legs be of unequal bores, then the heights must be calculated accoi ngly.

"On land, this instrument may be left out exposed all night, &c. but at sea it must always be held up by the hand in a perpendicular position, whether it be used when only half full of water, or when quite full; which last will be frequently found to be the only practicable method during the night.

"The use of the small tube of communication, *a b*, is to check the undulation of the water, so that the height of it may be read off from the scale with ease and certainty. But it is particularly designed to prevent the water from being thrown up to a much greater or less altitude than that which the wind can sustain.

"The height of the column of water sustained in the wind-gauge being given, the force of the wind, upon a foot square, is easily had by the following table, and consequently on any known surface.

Height in inches of the water in the gauge.	Force of the wind on one square foot.	Common designations of such winds.
12	62.500	
11	57.293	
10	52.083	Most violent hurricane.
9	46.875	
8	41.667	Very great hurricane.
7	36.548	Great hurricane.
6	31.750	Hurricane.
5	26.041	Very great storm.
4	20.833	Great storm.
3	15.625	Storm.
2	10.416	Very high wind
1	5.208	High wind.
0.5	2.604	Brisk gale.


Fig. 1
Fig. 2
Fig. 3
Q
L
P
K
Fig. 4
Fig. 5
W
B
C
Fig. 7
Fig. 6
E
D
C
Fig. 8
Fig. 10
A
D
R
B
Q
Fig. 11
F
G
K
L
Fig. 9
Fig. 12

Lind's wind-gauge.

Height in inches of the water in the gauge.	* Force of the wind on one square foot.	Common designations of such winds.
0.1	0.521	Fresh breeze.
0.05	0.260	Pleasant wind.
0.025.............	0.030	A gentle wind.

When the height of the water is not exactly mentioned in the table, then that height may be separated into such parts as are mentioned in the table, and the sum of the forces answering to such parts will be the force of the wind correspondent to the height in question; thus if the height of the water be 4.6 inches, then this height is equal to 4+0.5+0.1, which parts are all in the table; therefore

	lbs.
4 inches	20.833
0.5	2.604
0.1	0.521
	23.958

The sum, 23.958, expresses the force of the wind, when the height of the water in the guage is 4.6 inches. Any alteration that can usually take place in the temperature of the water, makes no sensible difference in this instrument.

In frosty weather this gauge cannot be used with common water. At that time some other liquor must be employed, which is not so subject to freeze, and, upon the whole, a saturated solution of common salt in water is the most eligible; but in that case, (since the specific gravity of a saturated solution of salt is to that of pure water as 1.244 to 1,) the forces which are stated in the preceding table must be multiplied by 1.244. Thus, if in the preceding example, the saturated solution had been used instead of water only, the force of the wind on a square foot would have been 29 pounds and a decimal; for 23.958 × 1.244=29.803752.

Of Winds.

Air, when in progressive motion, is called wind, in which state it becomes one of the most powerful agents in nature, its force increasing nearly as the square of its velocity, and its velocity often being prodigious.

The natural tendency of the atmosphere, as of all other bodies, is to remain in a state of rest; and if this tendency were not checked by unceasing causes, this fluid would everywhere be stagnant, and at the same elevation, would have the

same density. The density of air is diminished by an increase of temperature; that is, the more it is heated, the more space it takes up, and consequently the less is its pressure, bulk for bulk, on the surrounding air. This being the case, and the contrary, when its density is increased by cold, being equally true, it follows, that when any particular tract of air is heated or cooled more than the rest, the heavy parts will press it upwards, and occupy its place; and the atmosphere will not be at rest, until the equilibrium of its parts, in heat and density, takes place.

Dr. Franklin was the first who observed, that winds originate at the precise point towards which they blow. Thus, in going out of a large town, in winter, a wind is met in every point of the compass, because the air in the town being rarefied by so many fires, and the breathing of the people, is forced to ascend, by the pressure of the colder and denser air of the country on all sides of it. Partial changes of temperature are therefore the chief general causes of all winds, and it is the business of man, with respect to this subject, to discover where and in what degree they occur, in order to account for the individual phenomena. The attraction of the sun and moon is on good grounds supposed to occasion winds, and D'Alembert calculates, from the theory of gravitation, that the influence of these bodies in their daily motions, is sufficient to produce a continual east wind about the equator. When, therefore, attraction coincides with the heat, to produce an aërial tide, the combined effect may be very considerable; but the observations hitherto made, afford but scanty means of determining how much, in any case, may be attributed to attraction. It is to be remarked, however, agreeably to the observations of Bacon, Gassendi, Dampier, Halley, and others, that the periods of the year most likely to have high winds, are the two equinoxes; that storms are more frequent at the time of new and full moon, especially those new and full moons that happen about the equinoxes; that, at periods otherwise calm, a small breeze takes place at the time of high-water; and that a small movement of the atmosphere is generally perceived a short time after the noon and the midnight of each day. Whatever may be the influence of the sun and moon, in occasioning winds by their attraction, that of the moon will be the greatest, for the same reason, and in the same proportion, that her influence is the greatest, in producing the tides of the ocean.—See page 591, vol. I.

The winds are usually divided into three classes, viz. the general, the periodical, and the variable winds.

The most general of all winds, prevails within the limits of

30 degrees on each side of the equator, in the Atlantic and Pacific oceans, where the wind is almost always easterly; inclining a little towards the north-west when the sun is near the tropic of Cancer, and towards the south-west when the sun is near the tropic of Capricorn. This remarkable wind is called the *trade-wind*, and as it evidently follows the course of the sun, it appears undeniable that the sun is the cause of it. This wind, about the equator, or middle part of its track, always blows either exactly or very nearly from the east; but, even when the sun is at or near the equator, towards its northern boundary, it deviates more and more from the east towards the north: and towards its southern boundary it deviates more and more from the east towards the south. The manner in which the sun causes the trade-winds, seems to be generally agreed upon. By the great heat of the sun in the equatorial regions communicated first to the earth, and from the earth to the atmosphere, the air in those parts is greatly rarefied, and consequently is unable to sustain the pressure of the colder, denser air at both the poles. From the poles, therefore, the air rushes down to displace the rarefied air of the equator, and as the heat between the tropics is great at all times of the year, the constancy of the cause produces a correspondent constancy of effects. It might be expected from this explanation, that the trade-wind would be directly north on the north side of the equator, and directly south on the south side of it; but it must be recollected, that while the air is thus rushing from the poles, the earth is whirling round from west to east; at the equator, any given point is by this means carried 15 geographical miles in a minute, but this motion gradually diminishes towards the poles, where it is nothing. Now as the atmosphere partakes of the motion which belongs to that portion of the earth upon which it has been long enough incumbent, it is obvious that the air proceeds from parts where its diurnal velocity is small, to parts where this motion must be very considerable, before it can accompany the earth; and as an increased diurnal velocity cannot be received in an instant, the winds from the north and the south pass obliquely over the earth, and meeting each other obliquely at the equator, combine, with the motion of the sun from east to west, to produce there a wind directly east.

Of the periodical winds, the most remarkable are those called the *monsoons*, which blow for six months in one direction, and for six months in an opposite one. They are confined to the tropics, and are deviations from the regularity of the trade-winds, of half-a year's duration, because, for half the year, the monsoons mostly coincide with the general trade-wind. Their

origin appears to be owing to the circumstances of the different degrees of heat communicated to the air by water, and particular tracts of land. Low and level countries, other circumstances being the same, are of all parts of the earth most intensely heated by the sun; high countries and lofty mountains are of all parts of the earth the least heated by the same cause; while the ocean is heated in a middle degree, and from the uniformity of its level, and composition, the same degree of exposure to the sun's rays tends to produce on every part of it the same effect. It requires no particular explanation, that any given portion of the earth's surface can only heat the atmosphere in proportion to the degree in which it is heated itself; but this being admitted, it is evident that the sun, in his annual motion, becoming or ceasing to be vertical to vast tracts of ocean, deserts, or mountains, must necessarily produce various changes deviating from the ordinary course of the trade-winds. When the sun approaches the tropic of Cancer, Persia, Bengal, China, and the adjoining countries, become so much more heated than the sea to the southward of those countries, that the current of the general trade-wind is interrupted, and a wind is observed to blow, at that season, from the south to the north, contrary to what would be experienced if the whole had been ocean. But as the high mountains of Africa, during the whole of the year, are extremely cold, the low countries of India, to the eastward of it, become hotter than Africa in summer, and the air is naturally drawn thence to the eastward. From the same cause it follows, that in the Indian ocean, the trade-wind is converted into a monsoon, that blows in a north-east direction, contrary to that of the general trade-wind, in open seas of the same latitude; but when the sun retires towards the tropic of Capricorn, these northern parts become cooler, and the general trade-wind assumes its natural direction. To the southward of the equator, no monsoon takes place except in that part of the ocean adjoining to New Holland, where the same causes concur to produce a monsoon as in the northern tropic. From October till April, the monsoon sets in from the north-west to the south-east, opposite to the general course of the trade-wind on the other side of the line; and here also the general trade-wind resumes its usual course during the other months, which constitute the winter season in these regions.

A great variety of facts respecting winds, have been ascertained by different persons; some of the most remarkable of them are subjoined, and the statement will shew that no theory has been formed which accounts for the immediate cause of

all partial winds in a satisfactory manner. In the Atlantic ocean, at the distance of about 300 miles from the African coast, between the north latitudes of 10 and 28 degrees, seamen constantly meet with a fresh gale of north-east wind.

Across the Atlantic ocean, on the American side of the Caribbee islands, it has been observed, that the above-mentioned north-east wind becomes easterly, or seldom blows more than a point from the east on either side of it.

These trade-winds, on the American side, are often extended as far as the thirty-second degree of north latitude, which is about 4 degrees farther than their extension on the African side. Also, on the south side of the equator, the trade-winds extend 3 or 4 degrees farther towards the coast of Brazil on the American side, than they do near the Cape of Good Hope, or African side.

Between the latitudes of 4 degrees north and 4 degrees south, the wind always blows between the south and east. On the African side, the winds are nearest to the south; and on the American side, nearest to the east. In these seas, Dr. Halley observed, that when the wind was eastward, the weather was gloomy, dark, and rainy, with hard gales of wind; but when the wind turned to the southward, the weather generally became serene, with gentle breezes approaching to a calm. These winds are somewhat changed by the seasons of the year: for when the sun is far northward, the Brazil south-east wind gets to the south, and the north-east wind to the east: and when the sun is far south, the south-east wind gets to the east, and the north-east wind on this side of the equator goes more towards the north.

Along the coast of Guinea, from Sierra Leone to the island of St. Thomas (under the equator) which is above 1500 miles, the southerly and south-west winds blow perpetually. It is supposed that the south-east trade-wind, having passed the equator, and approaching the Guinea coast within 240 or 300 miles, inclines towards the shore, from the rarefaction of the air over the land there, and becomes south, then south-east, and gradually, as it comes near the land, it inclines to the south, south south-west, and close to the land it is south-west, and sometimes west south-west. —This tract is subject to frequent calms, and to sudden gusts of winds called *tornadoes*, which blow from all points of the horizon.

Between the latitudes of 4 and 10 degrees north, and between the longitudes of Cape Verd, and the easternmost of the Cape Verd Isles, there is a tract of sea, where calms are almost perpetual, attended with terrible thunder and lightnings,

and such frequent rains, that this part of the sea is called *the Rains*. It is said that ships have sometimes been detained whole months in sailing through this tract of six degrees. The cause of this seems to be, that the westerly winds setting in on this coast, and meeting the general easterly wind, the two winds balance each other, and cause the calms; and the vapour carried thither by the hottest wind, meeting the coolest, is condensed, and occasions the frequent rains.

Between the southern latitudes of 10 and 30 degrees, in the Indian ocean, the general trade-wind about the south-east by south, is found to blow all the year long in the same manner as in the like latitude in the Ethiopic ocean, and during the six months, from December to May, these winds reach to within two degrees of the equator; but during the other six months, from June to November, a north-west blows in the tract, lying between the latitudes of 3 and 10 degrees south, in the meridian of the north end of Madagascar, and between the latitudes of 2 and 12 degrees south, near the longitude of Sumatra and Java.

Between the island of Madagascar and the coast of Africa, and thence northward as far as the equator, there is a tract in which, from April to October, there is a constant fresh south south-west wind, which to the northward changes into the west south-west wind, blowing at the same time in the Arabian sea.

To the eastward of Sumatra and Malacca, on the north side of the equator, and along the coasts of Gambodia and China, quite through the Philippines as far as Japan, the monsoons blow northerly and southerly; the northern setting in about October or November, and the southern about May. These winds are not quite so certain as those in the Arabian sea.

Between Sumatra and Java to the west, and New Guinea to the east, the same northerly and southerly winds are observed; but the first half-year monsoon inclines to the north-west, and the latter to the south-east.—These winds begin a month or six weeks after those in the Chinese seas set in, and are quite as variable.

The monsoons, and other winds of nearly the same character, do not shift from one point to its opposite all at once. In some places the time of change is attended with calms, in others with variable winds of no great strength; and in others, as frequently occurs on the coast of Coromandel and China, with violent tempests.

On the greater part of the coasts of lands situated between the tropics, the wind blows from the sea towards the shore in the day-time, and from the shore towards the sea in the night

These periodical winds, which are slight and partial interruptions of the trade-winds, are termed the *land and sea breezes*. The cause of them is, the difference in temperature between the air over the land and that over the water: the ocean acquires and parts with its heat slowly; the short space of a night or a day makes but little difference with it; with the land, on the contrary, the difference in temperature is very considerable between the day and night, consequently, during the day, the air over the land becomes much hotter than that over the sea, a breeze of course sets in from the sea; and during the night, when the land air is coolest, the breeze will be from the land to the sea, to displace the more rarefied air over the latter.

The variable winds, which principally appertain to the countries between the tropics and the poles, are referable to the same general origin as other winds, but they are modified by so many circumstances, that they cannot be foretold, like the trade-winds, and monsoons, the laws they observe having not yet been discovered. It is evident, however, to common observation, that some winds in every place are more prevalent than others. At Liverpool, the winds are westerly for nearly two-thirds of the year, not successively, but on the average of the twelve months; yet strong westerly winds have not unfrequently prevailed so uninterruptedly for six or eight weeks, that vessels in port have been wind-bound for the whole of that time. The prevailing winds at London, as ascertained by the registers of the Royal Society, stand as follows:

Winds.	Days.	Winds.	Days.
South-west	112	South-east	32
North-east	58	East	26
North-west	50	South	18
West	53	North	16

The same register shews that the south-west wind blows more upon an average in each month of the year than any other, particularly in July and August; that the north-east prevails during January, March, April, May, and June, and is most unfrequent in February, July, September, and December; the north-west occurring more frequently from November to March, and seldomer in September and October, than in any other months.

In the fifth volume of the Statistical Account of Scotland, is inserted the following table, by Dr. Meek, near Glasgow; it was deduced from seven years' close observation.

Winds.	Days.	Winds.	Days.
South-west	174	North-east	104
North-west	40	South-east	47

The temperature of a country is increased or diminished by winds, according as they come from a hotter or colder part of the world. "The winds," observes General Roy, "seem to be dryer, denser, and colder, in proportion to the extent of land they pass over from the poles towards the equator; but they appear to be more moist, warm, and light, in proportion to the extent of ocean they pass over from the equator towards the poles. Hence the humidity, warmth, and lightness of the Atlantic winds to the inhabitants of Europe. On the east coasts of North America, the severity of the north-west wind is universally remarked; and there can scarcely be a doubt, that the inhabitants of California, and other parts on the west side of that great continent, will, like those on the west of Europe, feel the strong effects of a north-east wind."

Some of the variable winds which prevail in warm countries, are distinguished by particular names, and possess very extraordinary qualities. The *harmattan* is a wind which blows from the interior of Africa towards the Atlantic ocean. It prevails in the months of December, January, and February; its duration is sometimes only a day or two, sometimes five or six days, and sometimes, though rarely, it extends to fifteen or sixteen days. It is always accompanied with a fog or haze, that disrobes the sun of his splendour, and the particles of which are deposited on the leaves of trees and other objects, giving even the skins of the negroes a whitish appearance. Such is the extreme dryness of this wind, that it withers the whole vegetable creation, and the grass becomes like hay. The natives take the opportunity it offers them of clearing the land, by setting fire to trees and plants, while they are exhausted by this wind. Furniture suffers severely, the best seasoned wood shrinking, and flying to pieces at the junctures held by glue or any other cement. The human body is also affected, so that if the harmattan continues four or five days, the scarf-skin peels off, and though the air is cool, it excites a troublesome sensation of pricking heat. Notwithstanding these effects, the wind is salubrious, stopping infection, and removing the virulence of distemper, with an efficacy not less remarkable than its other qualities.

The *sirocco* is a south wind, which generally blows in Italy and Dalmatia every year about Easter. It is supposed to blow from the burning deserts of Africa; and in some respects it resembles the harmattan, but differs from it in the important particular of being extremely unfavourable as well to animals as to vegetation. Its medium heat is 112 degrees. During its continuance, the inhabitants of the countries where it prevails, never venture out of doors unless compelled by extreme

necessity, but closing every aperture that might admit the air into their houses, they keep continually sprinkling their apartments with water. In Sicily this wind seldom continues longer than thirty-six or forty hours; in Italy it sometimes continues twenty days, but is not so severe. It is commonly succeeded by the tramontane, or north wind, which in a short time restores the vigour of languishing nature. It has not been ascertained whether the effects of the sirocco may be entirely, as seems most probable, attributed to its heat, or to some mephitic mixture.

The *samiel*, or mortifying wind of the deserts near Bagdad, cannot, it is said, be breathed without destruction. The camels are reported to be instinctively aware of its approach, and to thrust their heads into the sand till it is blown over, which is commonly in a few minutes. The travellers throw themselves flat upon the ground, to avoid it; but if any one breathe it, his whole body becomes immediately mortified.

The wind which Bruce has called the *simoom*, appears to be of much the same nature as the samiel of other travellers, and he has described its effects, along with other remarkable phenomena of the winds in the desert, in the following striking manner: "We were here (in the deserts of Africa) at once surprised and terrified by a sight surely the most magnificent in the world. In that vast expanse of desert, from west and to the north-west of us, we saw a number of prodigious pillars of sand at different distances, at times moving with great celerity, and at others stalking on with a majestic slowness; at intervals we thought they were coming in a very few minutes to overwhelm us, and small quantities of sand did actually more than once reach us. Again they would retreat so as to be almost out of sight, their tops reaching to the very clouds. There the tops often separated from the bodies; and these, once disjointed, dispersed in the air, and did not appear more. Sometimes they were broken near the middle, as if struck with a large cannon shot. About noon, they began to advance with considerable swiftness upon us, the wind being very strong at north. Eleven of them ranged alongside of us about the distance of three miles. The greatest diameter of the largest appeared to me at that distance, as if it would measure ten feet. They retired from us with a wind at south-east; leaving an impression upon my mind to which I can give no name, though surely one ingredient in it was fear, with a considerable deal of wonder and astonishment. It was in vain to think of flying; the swiftest horse, or fastest sailing ship, could be of no use to carry us out of this danger; and the full per

suasion of this revited me as if to the spot where I stood, and let the camels gain on me so much in my state of lameness, that it was with some difficulty I could overtake them." In the course of a few days, "the same appearance of moving pillars of sand again presented themselves, only they seemed to be more in number and less in size. They came several times in a direction close upon us; that is, I believe, within less than two miles. They began immediately after sun-rise, like a thick wood, and almost darkened the sun; his rays shining through them for near an hour, gave them an appearance of pillars of fire. Our people now became desperate: the Greeks shrieked out, and said it was the day of judgment. Ismael pronounced it to be hell, and the Tucorories, that the world was on fire. I asked Idris if ever he had before seen such a sight? He said he had often seen them as terrible, though never worse; but what he feared most was the extreme redness of the air, which was a sure presage of the coming of the simoom. I begged and entreated Idris that he would not say one word of that in the hearing of the people, for they had already felt it at Imhansara, in their way from Ras el Feel to Teawa, and again at the Acaba of Gerri, before we came to Chendi, and they were already nearly distracted at the apprehension of finding it here.

"At half past four o'clock in the afternoon, we left Waadi Del Aned, our course a little more to the westward than the direction of Syene. The sands which had disappeared yesterday, scarcely shewed themselves at all this day, and at a great distance from the horizon. This was, however, a comfort but of short duration. I observed Idris took no part in it, but only warned me and the servants, that, upon the coming of the simoom, we should fall upon our faces, with our mouths upon the earth, so as not to partake of the outward air as long as we could hold our breath. We alighted, at six o'clock, at a small rock in the sandy ground, without trees or herbage, so that our camels fasted all that night. This place is called Ras el Sheah, or, by the Bishareen, El Mout, which signifies death, a name of bad omen. On the sixteenth, at half past ten in the forenoon, we left El Mout, standing, in the direction close upon Syene. Our men, if not gay, were, however, in better spirits than I had seen them since we left Gooz. One of our Barbarians had even attempted a song; but Hagi Ismael very gravely reproved him, by telling him, that singing in such a situation was a tempting of Providence. There is indeed nothing more different than active and passive courage. Hagi Ismael would fight, but he had not strength of mind to suffer. At eleven o'clock, while we

contemplated with great pleasure the rugged top of Chiggre, to which we were fast approaching, and where we were to solace ourselves with plenty of good water, Idris cried out, with a loud voice, 'fall upon your faces, for here is the simoom.' I saw from the south-east a haze come, in colour like the purple part of the rainbow, but not so compressed or thick. It did not occupy twenty yards in breadth, and was about twelve feet high from the ground. It was a kind of blush upon the air, and it moved very rapidly; for I scarce could turn, to fall upon the ground with my head to the northward, when I felt the heat of its current plainly upon my face. We all lay flat on the ground, as if dead, till Idris told us it was blown over. The meteor, or purple haze which I saw, was indeed passed, but the light air which still blew, was of heat to threaten suffocation. For my part, I found distinctly in my breast that I had imbibed a part of it; nor was I free of an asthmatic sensation till I had been some months in Italy, at the baths of Poretta, near two years afterwards."

Whirlwinds are generally supposed to consist in the convergence of winds from all parts to one point, on account of an extraordinary rarefaction of the air at that point. The currents acquire by their conflict at the place of meeting, and the velocity with which the rarefied air rushes upwards, a centrifugal force, which causes them to recede from the axis of rotation. When the centrifugal force thus acquired becomes equal to the pressure of the atmosphere, a space approaching almost to a vacuum, surrounds the axis or centre of motion, and as the whirl, by the action of the most prevailing wind, receives a progressive motion, it is obvious that the pressure of the atmosphere will be removed from every object passed over by the base of the vacuum, consequently destruction may be expected to mark its course. Partly by the removal of the atmospheric pressure, and partly by the whirling of the air surrounding the vacuum, loose bodies, a haystack, for example, will be raised with irresistible impetuosity, and dissipated at a great height.

When a whirlwind happens at sea, or over the surface of water, it forms the phenomenon called a *water-spout*. The water, for the same reason that it rises in a syringe, or a pump, or forms a fountain in an exhausted receiver, rises in the vacuum of the whirl, to the height of thirty or thirty-three feet, forming a pillar of water in the air, widest at the top; and the conversion of some of the upper part of this pillar into vapour, by the heat which originally occasioned the whirlwind, often forms a dense cloud. Water-spouts are observed

of all sizes, from the thickness of a finger to twenty-five feet in diameter, and at their junction with the ocean, the water appears to boil. If a large water-spout were to break over a ship, the vessel would either be destroyed, or would sustain very serious damage; when, therefore, they appear to be coming very near, the sailors avert the danger, by firing a cannon shot through them, and thus dissipating them. When not disturbed, they generally break about the middle. Several water-spouts are frequently seen within the space of a few miles, and they are attended in general with more or less noise, sometimes only a hiss, sometimes a murmur, and sometimes with a roar like that of an agitated sea. Water-spouts are sometimes driven from the sea, to a considerable distance over land, where they at length break, and deluge the plain, besides the mischief produced by the gyratory motion of the air. As thunder and lightning frequently attend whirlwinds and water-spouts, it has been supposed that electricity, if not the sole cause of these phenomena, has at least a share in their production; but electricity is produced whenever water is reduced into vapour, or vapour is converted into water; and the present state of knowledge on this subject is insufficient to decide whether the thunder and lightning may not be considered rather as the consequences than the causes of them.

A *tornado* is a whirlwind upon a large scale, being produced by the same causes; it is the whirlwind of tropical regions, and its effects are often tremendous. A moist vapour usually attends a tornado, the path of which is marked as if with rain.

Hurricane is another term for a storm of wind, seldom occurring, in its most terrific form, except in tropical climates. It is occasioned by the struggle of opposite winds, but does not, like the tornado, shift through all the points of the compass. It generally comes on with a northerly wind, and after veering to the east, it ceases; but the change is effected with such sudden impetuosity, that no ship can veer with it; whence it happens that the sails and yards are carried away, and sometimes the masts themselves twisted off. Of hurricanes it is usually observed, that they happen either on the day of the full, change, or quarter of the moon. If at the change of the moon, an unusual redness of the sky is observed, and at the same time, turbulence of the skies, swelling of the sea, a remarkable calm, and the hills clear of clouds, a hurricane may be expected at the full; or if these signs be observed at the full, a hurricane may be expected at the change.

It would be an interesting speculation to attempt at large the developement of the purposes effected by the winds; but in this place it must suffice to observe generally, that their cessation would accomplish the immediate destruction of animated existence. It is by the atmosphere's ceaseless propensity to motion, from every cause that varies its density, and the universal prevalence of such causes, that noxious effluvia are carried off as they are produced, to parts where, by chemical operations in the laboratory of nature, the air they have poisoned is absorbed or regenerated, and the whole mass of atmosphere preserved from corruption. And if we turn from this point of view to another, we find the services of the winds almost equally important in meliorating the fervour of a vertical sun, and equalizing the temperature over the whole globe. When these salutary and universal benefits are considered, the transient and partial effects of storms, especially when regarded as arising out of the rapidity with which the winds perform their office, can be regarded only as a slight sacrifice to the general good.

Of the Weather.

A knowledge of the approaching changes of the weather is of so much utility and importance to a great part of mankind, and of convenience to all, that it may seem surprising every indication of change which observation has yet furnished, has not been accumulated, and reduced into one system. It is true, however, that with respect to this, as on other occasions, those most interested are willing to content themselves with arguing from the appearances of the passing moment, or from a set of rules which, almost without effort, they have formed for themselves. It is to be admitted that farmers, and a great number of others, are generally furnished with a barometer or weather-glass; but this instrument, from its indications as to height not being combined with other circumstances, is seldom of much use to them, and not unfrequently leads them into errors, which might have been avoided, under a more comprehensive consideration. Dr. Halley appears to have been the first who drew up, from an extensive series of observations, the laws which govern the motions of the barometer, and it is to his conclusions and reasoning we shall first advert. He states the most general phenomena in eight propositions as the basis on which he proceeds.

1. In calm settled weather, when the air is inclined to rain, the mercury is commonly low.*

2. In serene, good, settled weather, the mercury is generally high.

3. Great winds, though not accompanied with rain, sink the mercury lowest of all, with relation to the point of the compass the wind blows upon.

4. The greatest heights of the mercury are observed during easterly and north-easterly winds.

5. In calm, frosty weather, the mercury generally stands high.

6. After great storms of wind, when the mercury has been low, it generally rises again very fast.

7. The more distant places are from the equator, the greater the range of the mercury in the barometer.

8. Within and near the tropics, the variation of the mercury is very little in all weathers.

Hence Dr. Halley considers the principal cause of the rising and falling of the mercury to be variable winds, which are found in the temperate zones, and which in England are remarkably inconstant. A second cause is the uncertain exhalation and precipitation of the vapours lodging in the air, which is thereby rendered heavier or lighter; but this cause is in a great measure dependent upon the former. The application of these principles to the phenomena, is next to be considered; and this will be done in the order in which the phenomena have been enumerated.

1. A low state of the mercury indicates rain, because the air being light, the vapours are no longer supported by it, they having become specifically heavier than the medium wherein they floated; so that they descend towards the earth, and, on their way, meeting with other aqueous particles, they incorporate together, and form little drops of rain. But the mercury's being at one time lower than at another, is the effect of two contrary winds blowing from the place where the barometer stands, whereby the air of that place is carried both ways from it, consequently the incumbent cylinder of air is diminished, and the mercury sinks. For instance, if in the German ocean it should blow a gale of westerly wind, and at the same time an

* The range of the mercury, it has been observed, is in this country about three inches, viz. between 28 and 31 inches; the mercury is therefore said to be low, when it is beneath the middle point, or 29½ inches; and high, when it is 4 or 5 tenths or more above that point.

easterly wind in the Irish sea; or if in France it should blow a northerly wind, and in Scotland a southerly, the effect in either case must be to exhaust and attenuate the air over England, where the mercury will subside, and the vapours, which before floated in those parts of the air of equal gravity with themselves, will sink to the earth.

2. A high state of the barometer is occasioned by two contrary winds, which, blowing towards the place of observation, accumulate the air of other places there; hence the incumbent cylinder of air being increased both in height and weight, the mercury, while thus pressed, necessarily stands high, and the vapours being supported, have no inclination to precipitate and fall down in drops; hence serene good weather attends the greater heights of the mercury.

3. The mercury sinks the lowest of all by the very rapid motion of the air in storms of wind; for the tract where these winds rage not extending all round the globe, the stagnant air which is left behind, as likewise that on the sides, cannot come in fast enough to supply the quantity removed by so swift a current; so that the air is attenuated where such winds blow, in proportion to their violence. It may also be supposed that the horizontal motion of the air diminishes its perpendicular pressure, and the great agitation of its particles dissipates the vapours, and prevents them from condensing into drops so as to form rain, otherwise the natural consequence of the air's rarefaction.

4. The mercury in this country stands the highest upon an easterly or north-easterly wind, because in the Atlantic ocean, on this side the 35th degree of north latitude, the winds are almost always westerly, or south-westerly; so that when the wind here comes up at east and north-east, it is checked by a contrary gale as soon as it reaches the ocean. By this means, agreeably to the second remark, the air over this island accumulates, and the mercury is high. In countries where the winds are under different circumstances, the same rule will not hold; and even in England, Dr. Halley had observed the mercury to be as low as 29 inches upon an easterly wind, but then it blew exceedingly hard, and therefore ought to be accounted for by the third remark.

5. In calm, frosty weather, the mercury generally stands high; perhaps because it seldom freezes but when the winds come out of the eastern and north-eastern quarters; or at least those winds blow at no great distance; for the northern parts of Germany, Denmark, Sweden, Norway, and all that tract whence north-east winds come, are subject, during the winter, to almost continual frost, which condenses the lower air, and

in this state it is brought hither by these winds; and being accumulated by the opposition of the westerly wind blowing in the ocean, the mercury is maintained at a more than ordinary height. A concurring cause is, the shrinking of the lower parts of the air by cold, a circumstance which must be attended with the descent of the upper parts of the atmosphere, to reduce the cavity made by the contraction.

6. After great storms of wind, when the mercury has been very low, it generally rises again very fast. After a long continued storm of south-west wind, it has been observed to rise an inch and a half in less than six hours. This happens, because the air, at the place of observation, being greatly rarefied during such continued storms, the neighbouring air rushes swiftly in to restore the equilibrium.

7. The variations are greater at places most distant from the equator; in the northern hemisphere, for example, the variation is greater at Stockholm than at Paris; because the more northern parts have usually greater storms of wind than the more southerly, by which the mercury should sink lower in that extreme; and then the northerly winds bringing the condensed and ponderous air from the neighbourhood of the pole, and that again being checked by a southerly wind at no great distance, and so heaped, must of necessity make the mercury in such case stand higher in the other extreme.

8. Lastly, the remark that there is little or no variation near the equinoctial, as at Barbadoes and St. Helena, is a confirmation of the hypothesis that variable winds are the cause of the variations of the mercury; for in the places above-named, there is always an easy gale of wind blowing nearly upon the same point, viz. east north-east at Barbadoes, and east south-east at St. Helena; and from the absence of contrary currents to exhaust or accumulate the air, the atmosphere continues much in the same state. During hurricanes, however, the mercury often descends very low, but it soon regains its settled state of about 29½ inches.

The preceding theory of Dr. Halley has been much contested; but it does not appear that any other agrees so extensively with the phenomena. All observations shew that the wind has, in our climate, a remarkable influence in raising and depressing the mercury; yet that winds are not so exclusively the cause as Halley is inclined to infer, Dr. Black, the most successful antagonist of the theory, has afforded strong evidence to conclude. This philosopher supposes that chemical changes cause the rising or falling of the mercury in the barometer; arguing, that water in the state of vapour,

requires a large quantity of caloric to keep it in that state, and the caloric thus absorbed becomes latent; when the caloric is liberated, its effect in rarefying the air, causes the mercury to fall, and when it is absorbed, the contrary effect ensues. This explanation does not do justice to the chemical theory; it merely points it out; our limits oblige us to leave speculation for the purpose of introducing some remarks more immediately useful.

It is particularly to be noted, that the height of the mercury is not the principal criterion for ascertaining the probable changes of the weather, but rather the relative motion of that fluid in the tube. Hence to predict the impending variations, we should correctly know whether the mercury is rising or falling at the time of observation. For this purpose, the following rules should be regarded: 1. If the surface of the mercury be convex, standing higher in the middle of the tube than at the sides, it generally indicates the rising of this fluid metal. 2. If the surface be concave, the mercury is then sinking. 3. If it appear to be level, or very nearly so, it is stationary. 4. If after shaking the instrument, that is, striking it so as to give it a slight vibratory motion, the mercury rises about half a tenth of an inch higher than it stood before, it is a proof that the air has become heavier; but if it sinks in the same proportion, it follows that the atmosphere is lighter. Hence, in referring to the barometer, the observed height of the mercury should not be considered the true height, unless the instrument has been previously shaken, because the metal, adhering to the sides of the tube, assumes not the station it would arrive at, until disengaged in the manner above-mentioned.

The eight propositions in which the chief phenomena of the barometer have been enumerated, were laid down with a view to explain their causes; but it will now be necessary to state more minutely the particular states of the weather which are likely to follow such changes.

1. The rising of the mercury generally presages fair weather, as its falling does the contrary, or rain, snow, high winds and storms.

2. In very hot weather, the sudden falling of the mercury portends thunder.

3. In winter, the rising indicates frost; and in frosty weather, if the mercury fall three or four divisions, there will certainly follow a thaw; but if it rise in a continued frost, it will be accompanied with snow.

4. When foul weather quickly succeeds, after the falling of the mercury, it will not be of long duration; nor are we to

expect a continuance of fair weather when it soon succeeds the rising of the mercury.

5. If, in foul weather, the mercury ascends considerably, and continues in an advancing state for two or three days successively, before the foul weather is quite over, then we may expect fine weather of some continuance.

6. If, in clear weather, the mercury falls remarkably for two or three days together, before the rain sets in, it is highly probable that much rain, and perhaps high winds, will follow.

7. An unsettled state of the mercury indicates changeable weather.

8. The words engraved on the register-plate, cannot be strictly relied on, to correspond exactly with the state of the weather at every observation. The upper words are most to be noticed, when the mercury removes from *changeable* upwards; as those on the lower part should be adverted to, when the mercury falls from *changeable* downwards. In other cases, they must be disregarded; for as the rising of the mercury in any part indicates a tendency to fair, and its falling to foul weather, it follows, that though it descend in the tube from *settled fair*, to *fair*, there may nevertheless be a little rain; and when it rises from *much rain* to *rain*, it shews only an inclination to become fair, and the wet weather may still continue, though in a less considerable degree than when the mercury began to rise. But if the mercury, after having fallen to *much rain*, should ascend to *changeable*, it predicts fair weather, though of a shorter continuance than if it had risen still higher; and, on the contrary, if the mercury stood at *fair*, and descends to *changeable*, it presages foul weather, though not of such duration as if it had fallen lower.

9. The mercury sometimes falls considerably without any remarkable change following it; this may arise from a distant storm, or even an earthquake.

10. If the mercury begin to rise steadily from a low state, and the wind change from the south or west to the north or east, fine weather may be expected.

11. A rapid movement of the mercury, even when rising, is an indication of bad weather, though not of long continuance.

12. The rising of the barometer is a more certain indication of fair weather, than its sinking is of rainy weather, because it often sinks for wind, as well as rain. If, therefore, while the barometer is sinking, the atmosphere still remain clear, wind may be expected.

With respect to prognostics of the weather, independent of the barometer, and which indicate the general state of an approaching season, Kirwan has deduced the following rules, from observations made in England during a period of 112 years, viz from 1677 to 1789:

1. When no storm has either preceded or followed the vernal equinox, the succeeding summer is in general dry, or at least so, five times out of six.

2. If a storm happen from an easterly point, on the 19th, 20th, or 21st day of May, the ensuing summer will, four times in five, be also dry.—The same event generally takes place, if a storm arise on the 25th, 26th, or 27th days of March, in any point of the compass.

3. Should there be a storm, either at south-west, or at west south-west, on the 19th, 20th, 21st, or 22d of March, the following summer is *wet*, five times out of six.

In England, if the winters and springs be dry, they are mostly *cold;* but if moist, they are generally *warm:* on the contrary, dry summers and autumns are usually hot; as moist summers are cold. Thus, if the humidity or dryness of a particular season be determined, a tolerably correct idea may be formed respecting its temperature.—To the above indications may be added the following maxims, which are the result of the observations made by various accurate observers.

1. A moist autumn, succeeded by a mild winter, is generally followed by a dry and cold spring; in consequence of which, vegetation is greatly retarded.

2. Should the summer be uncommonly wet, the succeeding winter will be severe; because the heat or warmth of the earth will be carried off by such unusual evaporation. It has been remarked, that wet summers are mostly attended with an increased quantity of fruit on the white-thorn and dog-rose; so that an uncommon fruitfulness of these shrubs is considered as the presage of an intensely cold winter.

3. A severe winter is always indicated by the appearance of cranes, and other birds of passage, at an early period in autumn; because these birds never migrate southwards, till the cold season has commenced in the northern regions.

4. If frequent showers fall in the month of September, it seldom rains in May; and the reverse.

5. On the other hand, when the wind often blows from the south-west, during either summer or autumn; when the air is unusually cold for those seasons, both to our sensations, and by the thermometer, the mercury at the same time being low in the barometer, profuse rain may be expected to close the season.

6. Great storms, rains, or other violent commotions of the clouds, often produce a kind of crisis in the atmosphere; so that they are followed by a regular succession, either of fine or of bad weather, for some months.

7. An unproductive year mostly succeeds a rainy winter.

8. Jones, in his physiological disquisitions, observes, that when it rains during a moon, the following change will probably produce clear weather for a few days, and then a continuation of rain; but, on the contrary, when it has been fair throughout, and it rains at the change, the fair weather will probably be restored about the fourth or fifth day of the moon, and continue as before. He adds, that he has made hay by these prognostics for twenty years, without having had the mortification of one disappointment.

9. Of the favourable prognostics drawn from the aspect of the sky, two of the most decisive, perhaps, are the following: an apparently great elevation of the celestial concave, and an evident disposition in the clouds to dissolve and disappear.

10. The gay, deep tinges of red and orange, reflected by the evening clouds, are welcomed by all as a favourable earnest of the ensuing day; but when the same colours are observed, widely spread, at the break of day, a contrary conclusion is inferred, and generally confirmed.

11. When the sky is entirely overcast, and small clouds, of a darker hue than the rest, are observed flying underneath, much rain may be expected.

12. When rain is very near, smoke and other vapours descend almost to the earth, the air being too light to support them; birds also fly lower than at other times.

13. When the dew, at the close of a summer's day, falls very copiously, the following day may be expected to be fine; but if the dew be deficient, the contrary may be looked for.

14. In collecting natural prognostics, observers have not failed to attend to the instincts of animals, when they appeared to have a relation to the purpose. In this pursuit, the poor despised spider appears most worthy of notice. These insects are observed to work differently at different times. If the weather be about to change, and become wet or windy, they make the terminating filaments that support their web uncommonly short. But if such threads be extended to an unusual length, the weather will remain serene for ten or twelve days, or for a longer period, according to their proportionate extension. On the contrary, when the spiders are totally inactive, rain will shortly follow; but if they continue to spin

during a shower, it is an indication that the rain will speedily cease, and be succeeded by calm fair weather.

15. Long, single filaments, like those of the spider's web, sometimes appear on grass, in considerable numbers, and stretched in various directions. When these are observed, a continuance of fine weather, for eight or ten days, generally follows.

To these prognostics of the weather, might be added many others; but perhaps the list has been already sufficiently extended. The work of observation, on all the changes of the atmosphere that can be detected by instruments, is now carrying on, to an extent without example in former times, by intelligent persons in various parts of the world, in this kingdom especially; and when, with the lapse of years, the necessary data have been accumulated in sufficient abundance, mankind will probably be furnished with deductions that will raise this important branch of knowledge far beyond its present state; and it is only as these come forward that prognostics of real value can be multiplied.

Of Sound.

The only remaining mechanical property of air which we have to notice, is that which renders it the medium of *sound*.

Any body which produces sound by collision from another, is called a *sonorous* or *sounding body;* though the term *sonorous* is more especially applicable to such bodies as produce a distinct and continuous sound, like a bell, or the string of a musical instrument, than to those which produce a dull and momentary sound, like that of clashing together two pieces of chalk.

If a bell firmly suspended by its centre, be struck by its clapper, or by a hammer, its circumference, if of considerable diameter, may be observed to vibrate backwards and forwards, which vibration will be still more easily perceived, if any point, fixed independent of the bell, be set at a short distance from its edge, as it will alternately recede from and approach to this point for some time. The first vibration has the greatest range, and each following one is less and less, till the bell regains a state of rest. While the vibrations of the bell continue, the sound dwells upon the ear, and decays as they decay; at least the difference of time between the cessation of the sound

and the cessation of the vibrations of the bell, is imperceptible, when the ear is within a short distance of the bell. The vibrations of the bell are communicated to the particles of air in contact with it; these particles give the impulse to those behind them; the motion is communicated by successive waves, in every direction; and when the air, in this state of motion, strikes upon the fine membrane, called the tympanum, in the cavity of the ear, it produces the sensation of sound. In proportion as the ear is at a distance from the sonorous body, other circumstances being the same, the sound is less loud and distinct, because, at an increased distance, the same quantity of motion in the air is spread over a greater space, and consequently it reaches the ear in a less concentrated state. The vibratory motion of the air, producing sound, cannot be rendered visible; but it may be felt by holding the hand over one of the pipes of a large organ, and it may be in some degree illustrated by a reference to the well-known appearance produced by impressing with any force the surface of smooth water; which, from the part where the force operates, immediately spreads in circular waves to a great distance, where there is sufficient room for the full effect to be observed. The waves are low in proportion to their remoteness from the spot where the motion emanated; and the last wave is not an extension of the first; but the first communicates the force which successively produces others; a circumstance that may be rendered evident by observing that the waves move faster than any light body floating upon the water, which could not otherwise be the case. The undulations exhibited by this experiment, in *one* direction, that is, upon a horizontal surface, correspond to those excited in the air, in *every* direction, by a sounding body.

The decay of sound has been supposed by some to be nearly in the direct ratio of the distances; while others have concluded it to be nearly as the squares of the distances. These differences have evidently arisen from the want of a certain method of measuring the intensity of sound, when the theory was to be proved mechanically; and an ignorance of the necessary data for establishing the theory mathematically.

The velocity of sound, though, like the rate of its diminution, the subject of different opinions, has been examined with considerable success, and on the authority of numerous experiments it is supposed to travel uniformly, at the rate of about 1142 feet in a second; or one mile in rather less than five seconds. Some philosophers have estimated its velocity higher, and others not so high; but it is reasonable to allow, that in measurements

of this sort, extreme accuracy must be considered an accidental acquisition, that cannot be proved; from the difficulty of measuring very minute portions of time, and the indistinct impression made by very distant sounds, together with the uncertain presence of various circumstances by which they may be modified. All sounds move with the same velocity; the gentlest whisper moves over the distance to which it extends, as rapidly as the report of a cannon over the same distance. A strong wind has been supposed to retard the progress of sound so much, that a sound advancing against it travels at the rate of one mile in a minute slower than when it is in its favour; but experiments are wanting to decide this question in a satisfactory manner. It has been found, that the report of a fire-arm is heard further, when the mouth of the piece is towards the person who hears it, than when it points any other way. In a great variety of other cases, the undulation is communicated to the air most strongly in one direction. An orator with a good voice may easily make himself heard at the distance of one hundred feet in a direct line before him; but he will not be heard with equal distinctness, at more than the distance of eighty feet on his right and left, or of forty feet immediately behind him. The situation of a speaker, and the shape of a room best adapted to oratory, should therefore be regulated by these data.

A knowledge of the velocity of sound is obviously applicable, in certain cases, to the purpose of determining distances. If a vessel is observed to fire a gun, and 8 seconds elapse between seeing the flash and hearing the report, the distance of that vessel is 8 times 1142 feet, or 1 mile 1285 yards; because the flash and the report are in reality made at the same moment, and the velocity of light is so great, that, at any terrestrial distance, it may be considered instantaneous. In the same manner may be estimated the distance of thunder, by noticing the number of seconds that intervene between seeing the lightning and hearing the thunder. Lightning passes with such velocity through the atmosphere, as to leave a vacuum behind it, and when the air that has thus been pushed aside rushes together again, the concussion produces the thunder, which instantly follows the flash That the particles of air are hard, and capable of producing such a sound by collision, is proved by the air-pump, in the experiment where, by the bursting of a bladder covering an open receiver, a column of air is caused to fall upon the pump-plate; and indeed the report of fire-arms is occasioned only by the force with which the air, that rushes in to fill the vacuum left at the exit of the charge, strikes the bottom of the piece.

A bell rung in condensed air makes a louder sound than when rung in air of the usual density; when the condensation is equal to two atmospheres, the sound is transmitted twice as far as by common air. From the impossibility of obtaining a perfect vacuum, we have no positive proof that sound does not take place in vacuo; but as, the more a receiver is exhausted, the more faint any given sound made in it becomes, till at length the collision of two bodies, which would be extremely loud in common air, cannot, from its faintness, be heard without an extraordinary degree of attention, a doubt can scarcely exist of the extinction of all sound in a perfect vacuum, unless our organs were in actual contact with the sounding body. It is agreeable to the facts here pointed out, with regard to the effect of the air's density on sound, that sound is transmitted further in valleys than on the tops of mountains.

Whatever diminishes the elasticity of the air, impairs its capacity of conducting sound. When the air is in a very moist state, the intensity of the same sound is less than at other times; and in the fogs of London, which sometimes, even at mid-day, produce a degree of darkness that prevents so large an object as a horse from being seen at a greater distance than two or three yards, the ear gives no notice of danger when it is often exceedingly imminent, by the noiseless approach of carriages, &c. till arrived within a very short distance.

When smooth and level ground is interposed between the sounding body and the hearer, the sound is heard at a much greater distance than when houses, walls, trees, crops of grain, &c. are interspersed in the path of the sound. Over the surface of smooth water, sound is conveyed admirably well, and may be heard at a greater distance than in any other way which nature affords. By placing the ear close to the ground or to the water, distant sounds may be heard, which would otherwise be entirely imperceptible. The Indians of North America are perfectly conversant with this practice.

The most elastic bodies are in general the most sonorous; and it is on the great elasticity of bell-metal, glass, &c. that their sonorous properties depend. Yet substances which possess very little elasticity are not without the power of conveying sound; for example, nothing is known to be less elastic than water, but the sound from two stones struck together under this fluid, has been heard at the distance of two miles by an ear placed in or close to the same body of water; the sound of a bell rung under water, and heard in air, will not reach so far as if rung in air, and its tone is about one quarter deeper.

The vivacity with which sounds are transmitted through solid substances, of various kinds, is very remarkable. The scratch made with a pin at one end of a piece of timber, fifty feet long, may be distinctly heard by an ear placed close to the other end, although the same sound could not be heard through the air at the distance of a dozen feet. In all cases, sound is diminished by a change of the medium of its conveyance.

Soft bodies, such as woollen cloth, absorb or deaden sounds; hence oratory and music are imperfectly heard behind a great number of people, or in apartments containing much-extended surfaces of a soft texture.

The difference of sounds, in point of strength, is easily understood by referring it to the power with which the sounding body in its vibrations strikes the air; but it may be inquired what makes the difference of tone, or between grave and acute? It is answered, that this is owing to the greater or less frequency of the vibrations of the sounding body in a given time. Quick vibrations produce acute sounds; slow vibrations, grave or deep sounds. Euler is of opinion, that no sound making fewer vibrations than 30 in a second, or more than 7520, is distinguishable by the human ear; but supposing this statement to be correct, it is obvious how numerous the differences of tone may be. An ear is considered to be bad or good, in proportion to the facility with which it distinguishes these differences. Sonorous bodies are said to be in unison, when their vibrations are equally frequent.

Any body susceptible of distinct vibrations may be put into full motion, by the repetition of the least imaginable impulse, provided that impulse be given at intervals precisely equal to double the time required for the body to perform one of its vibrations. For example, suppose a seconds' pendulum, properly suspended, to be at rest; we know that, when in motion, it comes to the same side at the expiration of every two seconds. At each interval of two seconds, therefore, impart to it, in the direction proper for its motion, a very small impulse, as by a puff of wind from the mouth, and its motion will soon be perceptible. The fact is, that the first impulse communicated some motion, though not enough to be visible; but as the impulses were repeated always, not when, with this invisible motion, the pendulum was coming towards but going from them; the accumulation of the motion in a short time became evident to the eye. This experiment is applicable to the explanation of a curious effect of sonorous bodies in unison. If one of two strings, which are in unison, that is, which perform their vibrations in equal times, be caused to sound, the other, as if actuated

by some spontaneous sympathy, will, if not at too great a distance, also begin to sound. Here the vibrations or pulsations of the air, although they may not be powerful enough to effect the purpose at once, produce an accumulated motion in the second sounding body, which would not be the case unless the successive impulses received by it corresponded to its proper motion, in the same manner as those given to the pendulum.

When the air, in a state of vibration, strikes upon a solid, regular surface, it is reflected by it in the same state, at an angle equal to the angle of incidence. An ear, therefore, situated in the direction of these reflected vibrations, perceives a sound similar to the original one, but apparently originating in a right line with its last direction, at a distance equal to the reflected and incident course. These reflected sounds are called *echoes*; they cannot, on account of the great velocity of sound, be distinguished from the original sounds within the space of fifty-five feet from the reflecting surface, therefore an echo must always be at that distance or more: when the reflecting surface is nearer, it is only said to increase the sound. As reflecting surfaces produce various differences, according to their distance, figure, and composition, the effects of echoes are very different. The sides of hills, buildings, rocks, the surface of water, are all capable of reflecting sound; and even thunder frequently owes its continuity to a reverberation from the clouds. A convex surface reflects sound indifferently, a flat surface well; and concave surfaces the best of all, particularly when the sounding body and the ear are in the direction of the centre of concavity: hence the effect produced by whispering domes and whispering galleries. In an elliptical chamber, if the sounding body be placed in one focus of the ellipse, an ear placed in the other focus will hear a much louder sound than if in any other situation. This follows from the nature of an ellipse, combined with that property of sound by which its angle of incidence is equal to the angle of reflection; for if, from any point in the circumference of an ellipse, two lines be drawn to the foci, they will make equal angles with the curve at that point. The whispering gallery in the dome of St. Paul's Cathedral, London, is a good example of this effect. A person turning his face towards the wall, on one side, speaks in a low whisper, which is more distinctly heard by a person at the opposite side of the dome, than by one close to him; and the shutting of a small door on one side, makes a noise like thunder on the other. Something of the same effect is observed, even when two semi-elliptical cavities, like niches, are situated

opposite each other, without any connecting wall; and sounds uttered in the focus of one of them, may be well heard in the focus of the other, though very indistinct at other points.

"It is in general known," says Goldsmith, "that caverns, grottoes, mountains, and ruined buildings, return this image of sound. Image, we may call it; for in every respect it resembles the image of a visible object reflected from a polished surface. Our figures are often represented in a mirror without seeing them ourselves, while those standing on one side are alone sensible of the reflection. To be capable of seeing the reflected image of ourselves, we must be directly in a line with the image. Just so it is in an echo, we must stand in a line in which the sound is reflected, or the repetition will be lost to us, while it may, at the same time, be distinctly heard by others who stand at a small distance to one side of us. I remember a very extraordinary echo, at a ruined fortress near Louvain, in Flanders. If a person sung, he only heard his own voice, without any repetition; on the contrary, those who stood at some distance, heard the echo but not the voice; but then they heard it with surprising variation, sometimes louder, sometimes softer, now more near, then more distant."

Ventriloquism, or the art of speaking in such a manner that the voice appears to proceed from any place or object at the option of the speaker, has been supposed by some to consist in the artful management of an echo; but the difficulty of producing by echo, the same sounds, in any variety of situation, seems an insurmountable objection to this explanation. It is a more probable hypothesis, that the art of the ventriloquist is that of mimicry, his acquirement of it being facilitated by the natural aptitude of the voice to admit of any modification, and completed by degrees, and diligent attention to the actual sounds he would imitate. Ventriloquists are in the habit of exerting their talent when not looked at, or, when observed, they divert attention from themselves by gesticulation. It may seem strange that so much uncertainty should prevail respecting the nature of an art which has occasionally at least been so publicly practised; but it must be considered, that the possessors of the secret have in general been anxious to make it gainful of money only; that the very few who have been above this, have preferred the admiration bestowed on an art supposed to be unacquirable, to the merit of a disclosure which might tend to place them on a level with others; and lastly, that scientific men have as yet had very few opportunities of examining those who have been remark able for this description of skill.

On the reflexibility of sound, depends the value of the hearing-trumpet, which consists of a tube, with one of its apertures very small, compared with the other. The smaller aperture is held to the ear, the other presented to the point from which the sound comes. The smaller aperture is only about a quarter of an inch in diameter, the other often four inches. Hence the quantity of motion in the air, which at its entrance was spread over the large area, becomes concentrated in its progress up the tube, which reflects the sound from its sides towards its axis. The sound is therefore much louder, but not so distinct; probably the latter effect arises from the best form of the hearing-trumpet not being understood, or the workmanship not well executed, and in part, no doubt, because these instruments cannot be made of any substance which is perfectly elastic.

The *speaking-trumpet* is in fact the same instrument as the hearing-trumpet, applied only to the purpose designated by its name. The mouth is applied to the smaller end, and its effect is to make its chief impression on the air, (and therefore to convey nearly the whole of the sound,) in the direction of its axis, so that an ear placed in the direction of the axis, will hear the speaker at a much greater distance than without such assistance. The most approved form of the hearing and speaking trumpets, is that of a hollow parabolic conoid.

ABSTRACT OF PNEUMATICS.

1. The air is the fluid which we breathe; with the vapours it contains, it is called the atmosphere.

2. The particles of air are solid and impermeable, like those of the hardest bodies.

3. The air is invisible, because of its great transparency; when unconfined, it is imperceptible to the touch, because its particles move among each other with a facility so great that we perceive no force to be required in displacing it; we move in it as if it had no pressure upon us, because its pressure is in every direction the same.

4. The weight of air is to that of water as 832 to 1.

5. The air expands in proportion to the diminution of the pressure upon it; it therefore becomes rarer as we ascend in the atmosphere, and at the height of 3½ miles, a given bulk of it takes up twice the space it would do at the surface of the earth.

6. The air-pump is a machine for exhausting the air out of vessels; but the best air-pumps have not so completely attained their object as to produce an absolute vacuum, or place void of air.

7. The rising of water in common pumps, is owing to the pressure of the atmosphere being removed from one part of the fluid, which therefore yields at that part by the pressure on the other parts, till the column of water sustained is equal to the column of air sustaining it.

8. *Suction*, unless so applied as to mean the pressure of the atmosphere, is a nonentity, and incapable of producing effects.

9. The pressure of the atmosphere, which is in general 15 pounds on every square inch, is not invariably the same, but is on a middle-sized person 1866 pounds less at one time than another; and when the pressure is greatest, we feel exhilarated rather than depressed.

10. On the variable pressure of the atmosphere, and the changes thereby occasioned, is founded the utility of the *barometer*, by which instrument the pressure is measured.

11. The best barometer is the common one, with a straight tube, and short scale of variation; other kinds, in contriving which, the extension of the scale of variation has been chiefly aimed at, are all more or less defective.

12. In observations for measuring the height of mountains, a thermometer must be used along with the barometer, in order that a due allowance may be made for the effects of temperature in lengthening or shortening the column of mercury; and the surface of the mercury in the cistern must be at a fixed distance from the scale, before the height of the mercury is read off.

13. The air may be condensed, or forced into less compass than it occupies at the surface of the earth, by means of a contrivance called a *condensing engine*.

14. When much condensed, the efforts of the air to expand are so great, that it may be employed as a powerful motive force. On this depends the properties of air-guns.

15. An *hygrometer* is an instrument for measuring the dryness or moisture of the atmosphere.

16. De Saussure's hygrometer is made of clarified hair: De Luc's, of a slip of whalebone cut across the grain.

17. The depth of rain which falls on the earth, is estimated by the quantity which falls within a small vessel called a *rain-gauge*.

18. The strength of the wind is measured by its power to support bodies out of the position of equilibrium.

19. The winds are the consequences of the variations constantly taking place in the density of the atmosphere, principally by the action of solar heat.

20. In Britain, the most prevalent wind is the south-west.

21. Variable winds are supposed to be the chief causes of the rising and falling of the barometer, which, in countries not subject to them, remains almost uniformly at the same height.

22. In deriving, from the barometer, prognostics of the weather, the tendency of the mercury to an upward or downward motion, rather than its absolute height at any time, is chiefly to be regarded.

23. When the air reaches the ear in a state of vibratory motion, it occasions the sensation of *sound*.

24. Bodies which produce the clearest and strongest sound, are in general the most elastic.

25. The quality of a sound, in point of tone, is determined by the greater or smaller number of vibrations made by the sounding body in a given time.

26. Sonorous bodies, when sufficiently near, cause each other to sound, although but one of them is struck, provided they be in unison, or disposed to make vibrations equally frequent.

27. An *echo* is the reflection of a sound, and cannot be heard unless the original sound have traversed the distance of about 110 feet.

28. Speaking and hearing trumpets act upon the principle of reflecting towards their axes, and thereby concentrating the sound transmitted through them.

HYDROSTATICS AND *HYDRAULICS.*

THE science of Hydrostatics treats of the pressure and equilibrium of fluids in general; but it is chiefly exemplified by the development of the mechanical properties of water, excepting so far as this fluid is dependent for its effects upon its motion. The science which teaches the laws of fluids in motion, and the application of fluids in that state to machines, is called *Hydraulics*. This distinction between Hydrostatics and Hydraulics, appears to make two sciences of subjects too intimately connected to be considered in any other light than as including only different parts of the same subject. We have therefore classed them together, and shall regard them as convenient heads for different chapters, on the properties common to non-elastic fluids.

OF HYDROSTATICS.

A fluid is a body whose particles yield to the least effort of partial pressure.

Fluids are of two kinds, viz. *elastic* and *non-elastic*. Elastic fluids are those in the state of air or gas; their bulk varies with the force compressing them, and in their other mechanical properties they resemble common air; the general laws relative to them are therefore to be derived from pneumatics. Non-elastic fluids, as oil, water, spirit of wine, are either absolutely or very nearly incompressible. These are the bodies with which hydrostatics is chiefly concerned.

The cause of fluidity has been the subject of much speculation; one opinion is, that the particles of fluids are spherical, in consequence of which configuration they slide over and among each other with prodigious facility. This assumption cannot be confirmed by experiment; no microscope being powerful enough to shew the component particles of any fluid; but it is favoured by the proofs we have of the numerous interstices of fluids; in water, for example, salt and various other bodies may be dissolved in considerable quantity, without enlarging its dimensions. According to this theory, also, the densities of different fluids are accounted for, by supposing their spherical particles to be of different sizes, the densest fluid having always the least particles; but why the

particles of various solids should assume a spherical figure by the action of fire, which fuses them, and some other figure when these bodies become solid in cooling, is not so easily determined. It is therefore the opinion of others, that fluidity is simply the consequence of the caloric combined with different bodies; the caloric surrounding these particles, and lessening their cohesion so much that they slide very easily over each other; when, however, so much caloric is abstracted, that the attraction of cohesion can operate, fluids become solid. Perhaps this theory would be improved, if the former were combined with it, rather than wholly rejected. Caloric, it may be supposed, will most easily lessen the attraction of cohesion between particles perfectly spherical, because these have the fewest points of contact; bodies may therefore be more or less easily rendered fluid, in proportion as their particles differ more or less from the spherical figure.

Though the particles of fluids have certainly a very small degree of cohesion to each other, yet it is not so small but that it may in a variety of instances be rendered visible: for example, it is the attraction of cohesion, that prevents a drop of water, placed gently on any dry surface, from expanding itself; and that allows a vessel to be filled above its brim with water, which could not happen if water were a perfect fluid.

The Florentine academicians, from the following experiment, inferred the total incompressibility of water. They took a globe of gold, which was the least porous of any body at that time known, and having filled it with water, they closed it up. They then subjected the globe to a great compressive force, which pressed the water through its pores, and caused it to form like a dew all over its surface, before any indent could be made in it. As a hollow sphere has a greater capacity than any other form whatever under the same surface, the academicians supposed, that the compressive power which was applied to the globe, must either force the particles of the fluid closer together, or drive them through the metal before the globe yielded in the slightest degree to compression. With respect to its precise object, therefore, this famous experiment is not entirely conclusive, because they had no means of determining whether the diminution of the internal capacity of the globe by pressure, was exactly equal to the quantity of water forced into its pores; but they certainly proved the extreme minuteness of the particles that could be forced through so dense a metal as gold. The inference drawn by the Florentines remained uncontradicted by any experiment, till about 1762. when Canton established some conclusions, which

shewed it was not to be accepted without limitation. With the barometer at 29½, and the thermometer at 50, he declares the following to be the results he obtained:

Compression of spirit of wine····	66	parts in a million.
Oil of olives······	48	ditto.
Rain-water·······	46	ditto.
Sea-water········	40	ditto.
Mercury·········	3	ditto.

These results he obtained in the following manner: He took a glass tube, about two feet long, with a ball at one end, of an inch and a quarter in diameter; he filled the ball, and part of the tube, with water which had previously been deprived of air as much as possible; he then placed it under the receiver of an air-pump, and removed from it the pressure of the atmosphere; under this treatment he observed that the water rose a little way in the tube. On the contrary, when he placed the apparatus upon a condensing engine, and by condensing the air in the receiver, increased the pressure upon the water, he observed that the water descended a little way in the tube. In this manner he found that water expanded one part in 21740 when the pressure of the atmosphere was removed, and submitted to a compression of one part in 10870 under the weight of a double atmosphere. He also observed that water possessed the remarkable property of being more compressible in winter than in summer; contrary to the effect on spirit of wine and oil of olives. Lest it might be supposed that the compressibility thus discovered might be owing to air lodged within the fluids employed, a quantity of water was caused to imbibe more air than it contained in a preceding trial; but its compressibility was not increased. These experiments, although upon the whole so apparently decisive of the questions they were instituted to determine, are yet not to be received without some caution; and in particular, the remark that the addition of a portion of so compressible a fluid as air, did not render water more compressible than before, is rather staggering, and is calculated to throw the veil of doubt over all the rest. It remains therefore for future investigation to fix the judgment of philosophers on this subject; in the mean time, even granting all the compressibility that has been contended for, the quantity of it is too small to be noticed in practice.

Persons at sea frequently try an experiment, which proves, in a great degree, the incompressibility of water. Having corked a bottle containing only air, and therefore called empty,

they tie a rope to it, and sink it to a considerable depth by a sufficient weight; on pulling up the bottle, they generally find it either broken, or the cork forced in: but on sinking to the same or even any greater depth, a bottle filled with water, they find it, when drawn up, to be uninjured, because the water resists compression, and therefore supports the bottle; which support, under the pressure at a great depth, the air cannot supply.

Fluids, as well as solids, press downwards, by gravitation, according to their quantities of matter, endeavouring always to attain the lowest place possible, or place nearest the centre of the earth; but they have this peculiarity, that they press in every direction alike, in proportion to their perpendicular height, and not their quantity. If one end of a glass tube be stopped with the finger, and the other be immersed in water, the air confined in the tube will prevent the water from rising far; but if the finger be withdrawn from the upper end, the water, by its upward pressure, will drive out of it a portion of air, and rise in it to the same level, as in the vessel: and this effect of rising to its level will take place whether the tube be held perpendicularly or aslant, or although the immersed part had ever so many convolutions. It is from this property of pressing in every direction, that the sides of vessels containing fluids, although at rest, must be made strong like the bottom; or if any difference be made, it must be gradual towards the top, because the pressure diminishes with the diminution of the column sustained.

The upward pressure of fluids may be proved in a very satisfactory manner, by the following experiment: Take a vessel AB, (fig. 1, pl. I.) suppose it to be a glass jar, that the experiment may be seen more agreeably, and pour into it a quantity of water. Place a glass tube KL, about the same length as the jar, or a little longer, upon a brass plate, the diameter of which should be rather more than that of the tube. The plate and the bottom of the tube must be ground very true, like the receivers and plates used in pneumatical experiments; so that water might be retained in the tube, if held down upon the plate by a slight pressure to prevent its removal. Fix a string *t* W, to the centre of the plate, and at the top of the tube make use of this string, to hold the plate to its bottom. In this state immerse the tube and plate in the jar of water, AB, till the plate is below the surface of the water at least about ten times its thickness. While still holding the tube with one hand, let go the string W, when it will be found that the plate will not fall off, because it is supported by the upward pressure of the water, which has

only access to one side of it. The upward pressure upon the plate, is produced by the pressure of the column of water surrounding the tube above the level of the plate; it therefore increases with the depth to which the tube is pushed down. On pouring water into the tube, the plate will be separated, and sink to the bottom. If the plate were of the same weight as an equal bulk of water, the water required to separate it, if not poured in so as to act by its velocity, must be sufficient to attain the same height in the tube as in the jar AB; but as the plate is heavier than an equal bulk of water, a quantity of water less by this excess, will suffice. If lead, gold, or any metal heavier than brass, be used, it will require to be sunk further, before it is supported; and lighter bodies will not require to be sunk so far.

To the preceding experiment, which exhibits the hydrostatical method of causing metals to swim, may be added another, in which wood and other bodies lighter than water refuse to swim. Take two pieces of wood, planed so perfectly flat, that when put together no water can get between them; cement one of them to the bottom of a jar, or any vessel capable of holding water; place the other piece upon the one thus cemented down, the two flat faces being of course in contact. Press upon the upper piece with a stick, to prevent its moving while the vessel is filled with water, after which, the stick being withdrawn, the loose piece of wood will remain in its situation, as steadily as the piece cemented down, because it is pressed by the weight of all the water over it; but if it be raised, however little, at one edge, some water will then get under it, which being acted upon by the water above, will immediately press it upwards, and from its lightness it will speedily reach the surface. From the difficulty of making two surfaces of wood impervious to water, the experiment shewing this effect of fluids, is usually conducted rather differently. A flat brass plate is cemented to the bottom of the jar, or vessel to contain the water, and a similar brass plate, to place upon it, has a lump of cork cemented to its back, so as to make the brass and cork together not heavier than most kinds of wood, or at most not so heavy as to prevent it from swimming, if laid upon the surface of water.

A due consideration of the equal pressure of fluids, explains a variety of effects which appear to be very extraordinary to the young inquirer. For example, this general proposition, which is of the most extensive application, may be deduced: *that the pressure of a homogeneous fluid, upon any given portion of the interior of a vessel containing it, is equal to the weight of a column of that fluid, which has the given portion in question fo*

its base, and the vertical extension of the fluid above it, for its altitude. By this rule it appears, that none but a vessel of equal breadth in every horizontal line, can have neither more nor less than the whole weight of its fluid contents pressing upon its bottom. If a vessel RS, fig. 2, pl. I, in the form of a truncated cone, with its bottom at its smaller end, contain water, the horizontal bottom of the vessel sustains no more weight than that of a column of fluid equal to its area, and in height equal to the depth of the fluid; the column sustained by the bottom of such a vessel as represented in the figure, is therefore no more than what would press upon the bottom of a vessel Y, fig. 3, the perpendicular height of the water in each vessel being the same. This rule holds, whatever may be the difference between such a column and the remaining contents of the vessel. But suppose the figure of the vessel to be reversed, as in fig. 4, the pressure on the bottom CD, is as great as if the vessel were to the top of the same diameter, and therefore equal to the capacity CDEF, marked out by the dotted lines. These maxims, the novice generally finds it difficult to understand, because they appear contradictory, and the latter seems like asserting that the bottom of a vessel bears more than the actual weight of its contents; yet they admit of incontrovertible proof, and the right understanding of them is essential to a knowledge of hydrostatics. They will be best understood in conjunction with the explanation of what is called the hydrostatical paradox, viz. that a quantity of fluid, however small, may be made to counterpoise a quantity, however large. To comprehend this, let us in the first place suppose we have a vessel in the form represented by fig. 5, of equal capacity in every part; on pouring a quantity of water into one limb, the water will rise in the other, and when left undisturbed, will subside at an equal height in both. In this there is nothing extraordinary; there is nothing, even in vulgar estimation, to hinder the equality of the columns, and equal columns must balance each other. The centre of gravity of the whole quantity of fluid attains and rests at the lowest place possible; this could not be the case, if a vessel thus uniform in its capacity, had not an equal weight in each limb; and an equal weight in each limb makes the level in both limbs the same. But take another vessel, such as represented by fig. 6: here one limb, NO, is very small compared with the other, ST, yet on pouring water into either tube, it rises in the opposite one, and on being allowed to rest, it remains at the same height in the broad as in the narrow side; therefore the water in the small tube NO, balances the column contained in the large one: and the same result would be obtained, whatever were the disparity

of the two capacities. Had the small limb been inclined in the position OV, the quantity of water in it would have been greater, because longer, but still each column would have had the same level. It is in this way that water always rises to its level. Here, as in the former case, with the vessel fig. 5, the centre of gravity attains the lowest place possible; but this could not happen, if the water in the large limb pressed that in the other higher than itself. Suppose the area of the column in the limb NO, to be one square inch, and the area of the other 60 square inches, then if the water in the limb ST were raised one inch, as by the pressure of a piston, that in the other would be depressed 60 inches, and *vice versâ*. This is a proof that the momentum of the water in each limb is the same; and bodies having equal momenta, however unequal their quantities of matter, must balance each other. When a solid body is impressed, the force must be sufficient to overcome the whole momentum of the body, or it will not move; but that such is not the case with a fluid, a variety of familiar instances might be adduced to prove; for example, when a butler taps a barrel, the force which he requires is not what would be necessary to push out of the way a solid body equal in weight to the contents of the barrel, but only so much as would be necessary to move a body equal to a column of water, of the diameter of the cork, and extending to the top of the fluid. If the force be equal to this, it is enough, and diffuses itself through the whole fluid. Considering the subject in this point of view, it must be evident, that the pressure at *e*, is no more than what it would be if the limb ST were of the same size as NO, the whole of the fluid, except at the open part, being supported by the bottom; therefore the effect must be the same as if the diameters of the columns of the water were equal, and they will necessarily have the same level. The pressure of fluids in this way may be shewn in a variety of forms. For example, to a cylindrical vessel FG, fig. 7, plate I, fix a piston L, which may be a circular piece of wood covered on the edge with leather, to make it water-tight. In the centre, or any other part of the piston, fix a tube LM, which must pass through the piston. Now fill the vessel FG with water, upon which place the piston with the tube. Then if the piston be loaded with any weight, for example, with one pound, the water in the vessel will be depressed, but it will at the same instant rise in the tube, suppose to H. If the piston be loaded with another pound, the water in the small tube will rise still higher, as to M, and every addition of weight will produce a proportionate effect. Here it is evident that a few grains of water sustain as much as the weight of a

column of water, whose base is equal to the diameter of the vessel FG, and its height equal to that in the tube. Thus the column LH, produces a pressure in the water contained in the vessel, equal to what would have been produced by the column *a c b d;* and as this pressure is exerted every way equally, the piston will be pressed upwards with a force corresponding to the weight of a column equal to the bulk of *a c b d,* consequently if *a c b d* would weigh a pound, LH will sustain a pound: at least such is the estimate in theory, and the only deviation from it in practice is occasioned by friction.

When a machine is constructed expressly for the purpose of shewing, in the most striking manner, that the pressure of fluids is as their perpendicular heights, and that a quantity, however small, may be made to support a weight, or another quantity, however large, it is generally made in the form of what is called the *hydrostatical bellows.* This machine is represented by fig. 8; it consists of two circular boards, suppose about twenty inches in diameter; these boards are connected by means of strong leather, which entirely surrounds them, and permits them to open and close like a pair of common bellows, with this difference, that they open equally all round, and therefore the boards always remain parallel to one another. The leather, at its junctures, is well secured, and the whole machine is water-tight. In the upper board is fixed a pipe W, communicating with the interior, and reaching above to a considerable height, suppose five feet. Through this pipe let some water be poured into the bellows, and the upper board will be observed to rise a little; place a weight of 100 pounds upon it, pour in more water, and it will be found no obstruction to its rising further; increase the weight to 300 pounds, and the pressure of the water in the tube will overbalance the whole; add water, till the leathers are at their utmost extension; the water will then fill in the tube, and the upper board cannot be depressed, nor the water forced out of the small tube, until the pressure upon it is more than that of a column of water, whose diameter is equal to that of the interior of the bellows, and its height equal to that in the tube; by increasing therefore the length of the tube, a most enormous weight might be raised by the pressure of a few ounces of water. The effect appears wonderful, and disproportionate to the cause; to the cause we must therefore now advert. In reference to figs. 5 and 6, it has been shewn, that both equal and unequal columns of water, by the regular law of gravitation, must balance each other; and that therefore, in such vessels, the water attains the same level in each limb: the admission of the reasons

proving this, is all that is necessary to the explanation of the effects of the bellows. Suppose a hole to be made in any part of the upper board, as at *f*, and another tube to be inserted there; the water would certainly rise, as in the vessels figs. 5 and 6, to the same level in them both, and supposing the board to be filled with tubes, the water would attain the same level in them all, because any two pipes would in fact form a vessel like fig. 5 or 6, according as the tubes were equal or unequal. Suppose a hole at *f*, to be of the same diameter as the interior of the tube, and fitted with a piston; then if the tube contained two ounces of water, the piston would sustain a weight of two ounces, without being depressed. If the area of the hole were twice that of the bore of the tube, two ounces in the tube would sustain four ounces on the piston. In this manner, every part equal to the bore of the tube is pressed upwards with a force equal to the weight of fluid in the tube. Hence if the proportion subsisting between the area of the interior of the tube and that of the bellows be multiplied by the weight of water in the tube, the product will express the force with which the boards are separated. Thus suppose the area of the board to be 300 inches, and that of the tube to be a quarter of an inch, they will be to one another as 1200 to 1, and supposing the tube to be long enough to contain 4 ounces of water, $1200 \times 4 = 4800$ ounces, or 300 pounds, for the weight which four ounces of water will support when thus applied.

It will probably be understood, that an equal bulk of any fluid denser than water, such as mercury, would with this machine produce a greater effect; and any rare fluid, such as spirit of wine, not so great an effect.

A man, standing upon the upper board of the hydrostatic bellows, may, by blowing into the tube, condense the air sufficiently to raise himself up, and by having a stop-cock near the top of the tube, to prevent the egress of the air thus forced in, he will continue to be supported as long as he may chuse.

On the disposition of water to press upwards to the level of its source, depends the existence of springs, which always originate in higher situations than those in which they are found. Of this property, the ancients appear not to have been aware. When they had water to convey from one hill to another, as from P to Y, fig. 9, though Y is lower than P, they were at the expense of constructing an immense aqueduct to cross the valley in a right line from the source, without reflecting how commodiously the same object might be effected by a pipe conveyed in the direction *m n o*, either to the hill Y, or to another still more distant, if not higher than P, by a continuation of the pipe.

The pressure of water being as its perpendicular height, it becomes necessary to guard against its effects in the construction of canals and other reservoirs; for when a column of water insinuates itself under a bank, if its upward pressure exceed the resistance of the weight upon it, which might frequently happen, the bank will be destroyed. Such accidents sometimes occur, and appear like the effects of gunpowder; they are guarded against by lining the bottoms of the reservoir with clay, or some material impervious to water.

Of Specific Gravities.

The expression "specific gravity," is of frequent recurrence in scientific works; the explanation of it, and the method of determining the specific gravity of any body, forms an important branch of hydrostatics.

The specific gravity of a body is simply the expression of its weight, when compared with an equal bulk of distilled water. For example, the specific gravity of gold is to the specific gravity of water as 19 to 1; the meaning of which is, that a given magnitude of gold, for example a cubic inch, will weigh 19 times as much as the water that could be contained in a vessel, the capacity of which is precisely equal to one cubic inch. It has generally been agreed to reckon the specific gravity of water at unity, or 1, which may be considered as one ounce, one pound, or any other quantity once told, as it is in all cases an equal bulk of the different body that is to be compared with it; when, therefore, the specific gravity of the body is less than that of water, it is usually denoted by a decimal, to shew how many parts of a thousand it amounts to; thus if the specific gravity of water be 1, and the specific gravity of corkwood be .240, it signifies that if any quantity of water were divided into 1000 parts, an equal bulk of corkwood, if weighed in the air, will balance 240 of such parts.

The specific gravities of bodies might be obtained by comparing them with the weight of equal magnitudes of any homogeneous fluid as properly as with water; but as every difference in the density of the fluid would give different results, and as it is a source of great convenience to have a common standard of reference; as also water can be obtained in every country, and when distilled, is every-where of the same specific gravity, at equal temperatures, no fluid is better calculated to answer the purpose designed. Rain-water is almost equally pure, and will therefore answer almost equally as well

as distilled water, for taking specific gravities, especially if collected in the country.

When a solid body is wholly immersed in a fluid, as the fluid presses upon and touches at every point, it is evident that the quantity of fluid displaced, must be precisely equal to the bulk of the body immersed in it: consequently it follows that the greater the density of the body, that is, the greater its weight for its bulk, the less will be the quantity of fluid which any given weight of it can displace. This may easily be proved, by filling a basin or any other vessel to the brim with water, wetting the edge of the basin, that the water may not fill it above its brim; then, on putting any insoluble body into the water, it will be found that the quantity of water driven over, is exactly equal to the bulk immersed; hence if the body sink, the water displaced is equal to its whole bulk; if it swim, the water displaced is equal only to the bulk of so much of it as remains below the surface of the water in the basin.

When a body sinks in a fluid, of its own accord, it is because of its being heavier than an equal bulk of that fluid; in consequence of which it overcomes the upward pressure by which it is opposed; this upward pressure supposing the fluid to be water, is equal only to its bulk of that fluid, and therefore, after deducting the weight of its bulk of water, the remainder is the force with which it sinks. Thus if the weight of a body be three ounces, and the weight of its bulk of water be one ounce, it will sink in water with a weight of two ounces. This accounts for the different degrees of rapidity with which different bodies sink. It is obvious that the cause why bodies swim in fluids, must be the converse of that which causes them to sink, viz. they are lighter than an equal bulk of the fluid; and the force which is required to sink a swimming body, must in all cases be such as to make it press upon the water, so as to be rather more than an equipoise for its bulk of that fluid. If a body be just equal to its weight of any fluid, it will remain at rest in any part of the fluid.

From the verified remark made above, that the force with which a body sinks in water is less than what it weighs in the open air by the weight of its bulk of water, this hydrostatical axiom is plainly deducible, *that every body immersed in water, or any other fluid, loses just so much of its weight, as equals the weight of an equal bulk of the water or other fluid.* A knowledge of this truth often renders the most admirable assistance, in detecting the identity of substances, when all other characteristics, that can be conveniently resorted to, prove ineffectual; of this a memorable example and illustration, immedi-

ately resulted from its first discovery, which happened in the following manner.

Hiero, king of Syracuse, who flourished about 200 years before the birth of Christ, employed an artist to make him a regal crown of gold, and furnished a sufficient quantity of pure metal for that purpose. When the crown was finished, its weight was found to equal that of the gold delivered for it, yet the king suspected an adulteration. He applied to the celebrated Archimedes for the means of detecting the amount of the fraud; this philosopher could not for some time arrive at any satisfactory conclusion, but at length an accidental observation which he made, reminded him of the means he might employ. When stepping one day into a bath, he took notice that the water rose in proportion to the quantity of his body immersed in it; and immediately reflecting that a body of equal bulk with himself would raise the water in the same degree, though a body of equal weight, but not of equal bulk, would not raise it so much, he became instantly alive to all the consequences of this reasoning, and in the ecstasy of the moment, forgetting his clothes, he ran into the streets of Syracuse, exclaiming, "I have found it! I have found it!" He forthwith took masses of metal, each of them equal in weight to the crown, but one of them was of pure gold, the other of silver. These he separately let down into a vessel containing water, the rising of which, by the alternate immersion of the masses, could easily be determined by measure. He found that the silver displaced a greater quantity of water than its weight of gold; he then tried the crown, and found that it displaced more water than its weight of gold, but not so much as its weight of silver. By these means he discovered that the crown was not made of pure gold, and by comparing his observations on the bulk of water displaced by the crown, the gold, and the silver, he discovered the quantity of gold the crown actually contained.

As whatever weight a body is found to lose, on being weighed while suspended in water, is the same as the weight of a quantity of water equal to its bulk; hence to obtain specific gravities, it is not necessary to reduce solids to any given size, in order to compare them by measurement, but they are taken of any size or figure, and weighed first in air and then in water, by means of an instrument called a *hydrostatic balance.* This instrument is represented by fig. 10, plate I, and differs from a common balance chiefly in having a small hook under one of its scales; from this hook are suspended, by means of a horse-hair, a thread of silk, &c. the different bodies to be tried, so that they may be immersed in water without

wetting the scale. To adjust the weight with more facility, a stand is placed under the scale B, which may be made to touch the stand, or be raised above it, by turning the small milled head of a pinion at the upper part of the stem which supports the instrument; this pinion acting upon a rack. These balances are furnished by the mathematical instrument-makers, neatly made up in the most compact form, with the various requisites necessary in the course of using them; the experimenter should, in particular, have an accurate set of weights; a glass jar, F, about seven or eight inches high, which is to contain the distilled or rain water; a solid glass ball, M, or a glass bulb containing some mercury or other heavy body to make its weight about equal to that of a solid glass globe, the diameter of it to be from one inch to an inch and a half, and a bit of fine platina wire, about three inches long, should be affixed to it; it may be most conveniently made of some weight expressed in round numbers of grains: a small glass bucket, L, with a glass handle; two or three small phials, as shewn at K, wide at the mouth, in order that they may be easily filled, emptied, or cleaned; and a common thermometer, Q, that the temperature at the time of experiment may always be noted; a precaution which the exactness of modern philosophers renders indispensable to the value of an experiment, although it was formerly but little regarded.

To obtain the specific gravity of a single article, a common balance and weights will answer, and the horse-hair from which it is suspended may pass over the scale; but balances employed for precise and regular use, should at least turn with the 20,000th part of the weight contained in each scale; and the kind of weights adopted is not a matter of indifference; it is by far the most convenient to have them all of one denomination, and if this plan be adopted, the smallest denomination in use will be the most suitable, viz. grains. Demonstrations have been given of the smallest number of weights which will suffice for any weight within certain limits; but these are calculated to serve practical men but little; they cannot be supposed to have leisure for that nicety of selection which would be requisite if they were provided only with the smallest number of weights that would suffice; but require such a number as may comport in the highest degree with accuracy and expedition. "The error of adjustment," observes Nicholson, "is the least possible, when only one weight is in the scale; that is, a single weight of five grains is twice as likely to be true, as two weights, one of three, and the other of two grains, put into the dish to supply the place of the single five, because each of these last has its own probability of error in adjustment.

But since it is as inconsistent with convenience, to provide a single weight, as it would be to have a single character for every number, and as we have nine characters which we use in rotation, to express higher values according to their position, it will be found very serviceable to make the set of weights correspond with our numerical system. This directs us to the set of weights as follows: 1000 grains, 900 gr. 800 gr. 700 gr. 600 gr. 500 gr. 400 gr. 300 gr. 200 gr. 100 gr. 90 gr. 80 gr. 70 gr. 60 gr. 50 gr. 40 gr. 30 gr. 20 gr. 10 gr. 9 gr. 8 gr. 7 gr. 6 gr. 5 gr. 4 gr. 3 gr. 2 gr. 1 gr. 9-10ths of a gr. 8-10 gr. 7-10 gr. 6-10 gr. 5-10 gr. 4-10 gr. 3-10 gr. 2-10 gr. 1-10 gr. 9-100 gr. 8-100 gr. 7-100 gr. 6-100 gr. 5-100 gr. 4-100 gr. 3-100 gr. 2-100 gr. 1-100 gr. With these the philosopher will always have the same number of weights in his scales as there are figures in the number expressing the weights in grains. Thus 742.5 grains will be weighed by the weights 700, 40, 2, and 5-10ths."

The procedure to be adopted, in obtaining specific gravities, varies a little with the nature of the substance which is the object of the experiment. To these cases we shall now advert.

To obtain the Specific Gravity of Bodies which sink and are insoluble in water.

Suspend the body from the hook under the scale A, fig. 10, by means of a horse-hair, or any slender thread that will support it, and let it hang at the distance of five or six inches below the scale. Then let it be exactly counterpoised by weights put into the scale B, as in all ordinary weighing. When its weight in air has been ascertained, immerse it in water, with which, to be in readiness, the jar F has been previously almost filled, and the equilibrium of the beam will be immediately destroyed. Then if as much weight be put into the scale A, from which the body hangs, as will restore the equilibrium; or if as much weight be removed from the scale B as will produce the same effect, the weight thus added or subtracted, will be equal to the weight of a quantity of water as large as the body immersed; and if the weight of the body in air be divided by what it loses in water, the quotient will shew how much that body is heavier than its bulk of water. Thus, if a guinea, suspended in air, be counterbalanced by 129 grains in the opposite scale of the balance, and then, upon its being immersed in water, it becomes so much lighter as to require 7¼ grains put into the scale over it, or taken out of the opposite scale, to restore the equilibrium, it shews that a quantity of water, equal in bulk to the guinea, weighs 7¼ grains, or 7.25; by this sum

divide 129, the weight of the guinea in air, and the quotient will be 17.793, which shews that the guinea is 17.793 times as heavy as its bulk of water. In the same manner as the specific gravity of pure gold is known, any piece of gold may be tried; and if, upon dividing the weight in air by the loss in water, the quotient proves to be 17.793, or nearly so, the gold is good, as some alloy is always added to it, that it may be harder, and fitter to bear the attrition it is subject to in the course of circulation; if the quotient be 18, or between 18 and 19, the gold is very fine; but if it be less than 17, it contains too large a proportion of some inferior metal.

By thus weighing a body in air, then in water, and dividing the weight in air by the loss in water, the specific gravities of all bodies that sink and are insoluble in water, may easily be ascertained, provided they be of a proper size and figure to be fastened by a hair or thread. But when the body is in the state of filings, grains, or pieces too small to be separately fastened, the glass-bucket L, fig. 10, may be made use of. Attach the bucket by a hair, to the hook of the scale; find its weight in air while empty; then put into it the substance whose specific gravity is to be found, and weigh it again; when the weight of the bucket by itself has been subtracted from its weight when loaded, the remainder will, of course, shew the neat weight of the substance in air. The bucket must then be weighed in water, both loaded and empty, and its weight, in the latter case, deducted from that in the former. Having thus obtained the weight of the substance alone, both in air and water, the case becomes the same as if the intervention of the bucket had not been required; viz. the weight in air must be divided by the weight lost in water, and the product will be the specific gravity sought.

To obtain the Specific Gravity of Bodies that swim in water.

When the specific gravity of wood, and other bodies lighter than water, is to be discovered, it is necessary to sink them by the assistance of lead or any other substance of sufficient density. Suppose an adequate piece of lead to be provided for this purpose, ascertain its weight in water, and the weight in air of the body it is employed to sink; then tie together both the lead and the body whose specific gravity is to be found, and weigh them in that state in water; the joint weight will be less than that of the lead alone, because the lead is buoyed up by the lighter body. Add the weight which the lead loses in water, when accompanied by the lighter body, to the weight of the lighter body in air, and this sum will be the weight of a

quantity of water equal in bulk to the lighter body; then divide this product by the weight of the lighter body in air, and the specific gravity required will be the quotient.

As wood, and many other substances, the specific gravities of which are sought, are porous and apt to imbibe water, which might affect the result, it is proper to give them a coat of varnish to prevent that effect.

To obtain the Specific Gravity of Salts, and other bodies soluble in water.

If the substance is not already in a fine powder, reduce it to that state; and then fill with it any convenient vessel, such as the phial K, fig. 10, and the weight of which vessel, when empty, has been ascertained. The substance must be level with the top of the vessel, after it has been pressed down as close as possible. From the weight in air of the phial thus filled, subtract the weight of the empty phial, by which the weight of its contents will be obtained; in the next place, take out the whole of the powder, and fill the phial in the same degree with water; weigh it again also in air, and deduct the weight of the phial as in the former case. Having now obtained the weight of equal dimensions of the powder and of water, it only remains to discover the relation between those weights, which is immediately fo[illegible] dividing the weight of the powder by the weight of the [illegible]; thus, if the salt weigh 60 grains, and the water 48, the [illegible] $\div 60 = 1.25$, the specific gravity desired.

To obtain the Specific Gravities of Fluids.

The specific gravity of a fluid may be obtained in the same manner as the specific gravity of a salt, viz. by noting the weight of a given measure of it, and the weight of the same measure of water, then dividing the former by the latter, and the quotient will be the answer. In order to fill a phial accurately with fluids, particularly corrosive acids, it is advisable to have a glass stopper to it, with a very small channel on one side; the phial being filled, and the stopper put in, the superfluous fluid escapes up the channel, where it may easily be wiped off, and the phial will be left exactly full.

Another method of finding the specific gravities of fluids, though not, perhaps, on the whole so accurate as the above, is often practised: it consists in calculations founded on the different weights which the same body will lose in different fluids. The body usually made and kept for this purpose, is a small glass globe, M, fig. 10, with a piece of platina wire affixed to it; glass and platina are selected, because there are no substances

conveniently to be obtained, on which so few liquids have any action. The experimenter should have the weights of his globe, in air and in water, accurately noted down. To have these ready for reference, he will find very convenient. Let him now take the weight fo the globe in any fluid, of which he wishes to know the specific gravity; and divide the weight lost by the globe in that fluid when compared with the weight of the globe in air, by the weight lost in water when compared with the weight in air: thus suppose the glass ball to weigh 140 grains in air, 80 grains in water, and 86 grains in the fluid to be tried; as the loss in water is 60 grains, and in the other fluid 54 grains, $54 \div 60 = 0.9$, the specific gravity of the other fluid.

The great importance, in many cases, of obtaining the specific gravities of fluids, not only with accuracy but expedition, has introduced several contrivances to render the use of the balance unnecessary. These have been distinguished be a variety of names and forms, but they all depend upon the same general principle, viz. if the same body be placed successively in different fluids, if its specific gravity be less than any of them, it will sink deepest into those which have the least density; therefore, as some fluids, such as distilled spirits, are strong in proportion as they are light; and others, such as sulphuric acid, are strong in proportion as they are heavy; to ascertain accurately the degree in which a body sinks in different fluids, may, it is clear, be employed to point out their specific gravity. The most common instrument acting on this principle, is called

The Hydrometer.

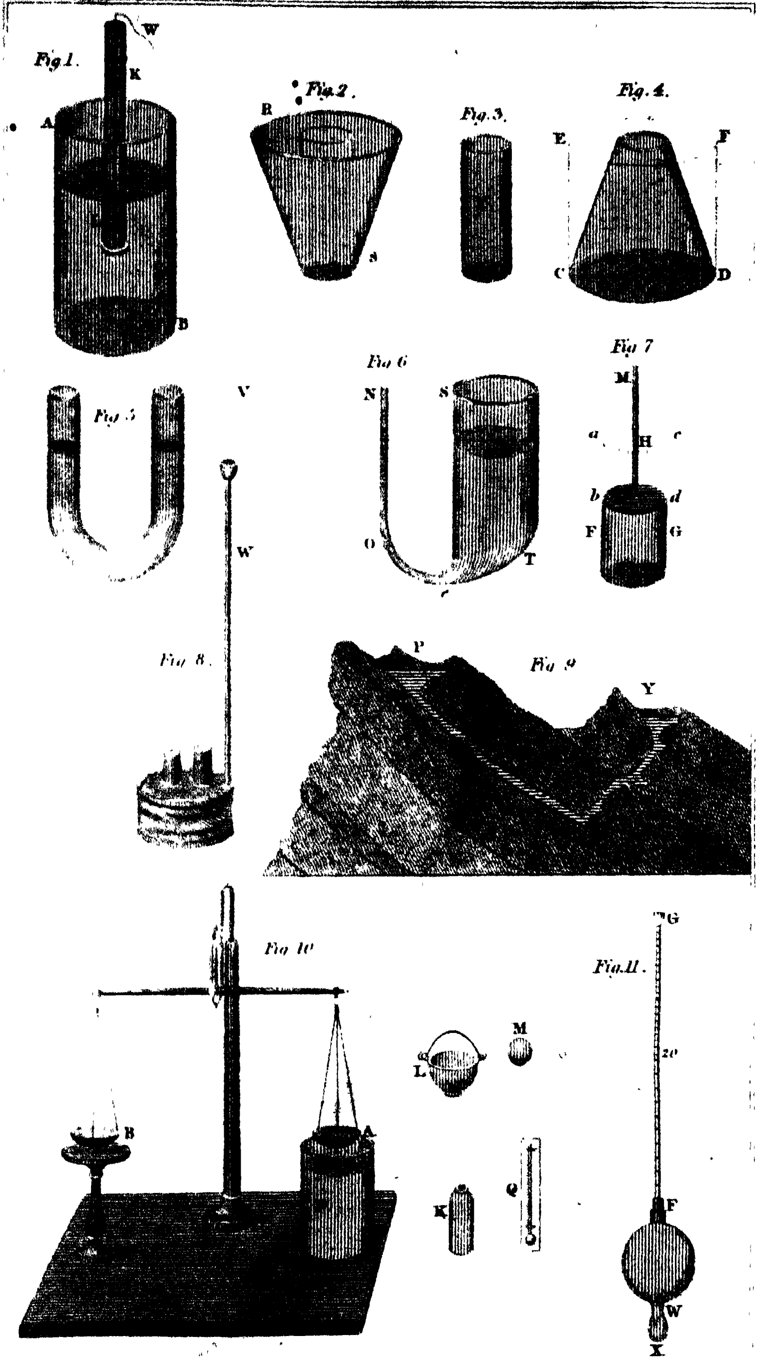
This instrument is usually made in the form represented at fig. 11, pl. I. It consists of a hollow ball, either of metal or glass, capable of floating in any known liquid. From one side of the ball proceeds a short stem, W, terminating in a weight or small ball X, which, if hollow, has a small quantity of mercury put into it. From the side of the ball opposite the stem W, proceeds another stem, FG, of an equal thickness throughout. The ball X is placed downwards in the fluid to be tried, and the weight it contains, serving as ballast, causes the stem FG to remain upright; in all cases, the weight of the instrument must be such that it will sink in the heaviest fluid required to be tried, to some part of the stem FG, which is graduated, and serves to shew the density of the fluid by the depth to which it sinks in it. When this instrument is swimming in any fluid, the part of the fluid displaced by it

as in other cases of swimming bodies, is equal in bulk to the part of the instrument under water, and equal in weight to the whole instrument. Now suppose the weight of the whole to be 4000 grains, it is evident we can use it to compare the different dimensions of 4000 grains of several sorts of fluids. For if the weight be such as to cause the ball to sink in water, until its surface come to the middle point, 20, of the stem; and afterwards, when immersed in some other fluid, the surface is observed to stand at one-tenth of an inch below the middle point, 20, it is apparent that the same weight of the fluid in either case, differs only in bulk, by the magnitude of one-tenth of an inch in the stem. Suppose the stem to be 10 inches long, and to weigh 100 grains, then every tenth of an inch will weigh one grain; and if the stem be of brass, which is about eight times heavier than water, the same bulk of water will be equal to one-eighth of a grain, and consequently to one-eighth of $\frac{1}{4000}$, that is, $\frac{1}{32000}$th part of the whole bulk. When the instrument is chiefly designed for proving the strength of spirituous liquors, the weight of it is such that it sinks in proof-spirit to the middle point, 20, of the stem, while in alcohol it sinks to the top G, and in water the ball at F is only just covered: then by dividing the upper and the lower parts G 20, and F 20, into ten equal parts each, when the instrument is immersed in spirituous liquor, it will immediately shew how much it is above or below proof.— Proof-spirit consists of half water and half pure spirit, or alcohol; and if poured out on gunpowder and set on fire, will all burn away, and the powder will take fire with a flash as in the open air; but if the spirit be not so highly rectified, the powder will be wet, and unfit to take fire. This mode of trial is, however, rather ambiguous, though not quite so much so as the mode of proving spirit by the size of the bubbles on its surface, after shaking it up.

The hydrometer constructed as above, cannot have a very extensive range; for if the stem be made heavy, small differences in density will be detected with great difficulty, and if it be long, it will be at the expense of portability. Another defect arises out of its equal divisions; for the density of spirit is not always in direct proportion to its purity; thus, if from twenty to thirty parts of spirit are mixed with from seventy to eighty of water, the two fluids combine more intimately and occupy less space than in other proportions. To increase the range of the hydrometer, it has been proposed to change the ballast or weight in the secondary ball, but the improvement of Fahrenheit is the most to be approved. Fahrenheit's hydrometer, like the common one,

HYDROSTATICS AND HYDRAULICS.

PLATE I.



consists of a hollow ball, with a counterpoise below, but the stem above is very slender, and terminates in a small dish. Round the middle of the stem is made a mark, which is merely a fine line. There are no divisions on the stem, which is always immersed in the fluid to be tried, up to the mark, by placing as much weight as may be required in the little dish at the top. Hence, as the part immersed is constantly of the same magnitude, and the whole weight of the hydrometer is known; this last weight, added to the weight in the dish, will be equal to the weight of fluid displaced by the instrument; and the specific gravity will be obtained by this rule: as the whole weight of the hydrometer and its load, when adjusted in distilled water, is to 1.000, so is the whole weight, when adjusted in any other fluid, to a fourth proportional, which is the specific gravity to be ascertained. This instrument is much superior to the hydrometer first mentioned: the greatest impediment to its sensibility, arises from the attraction or repulsion between the surface of the fluid and that of the stem; so that if the instrument have a tendency to sink, there will be a depression of the fluid all round the stem; or if, on the contrary, its tendency be to rise, the fluid immediately surrounding the stem will be higher than the rest of the surface. When, however, the surface of the fluid is exactly flat, the reflection of any straight lines, as of the frame-work of a window, will not be distorted, and by taking notice of such reflection from the part surrounding the stem, the adjustment may be made to the fortieth or fiftieth part of a grain. Hence if the instrument displace one thousand grains of water, the result will be very true to at least four places of figures. This degree of accuracy renders the hydrometer equal to a good balance; particularly for such fluids as do not differ greatly in density · and it therefore suits those, for example, who have only to take the specific gravities of spirits; those who wish to obtain, by the use of a single instrument, the specific gravities of fluids differing greatly in density, will be convinced, by a little experience, that the balance is the most portable and convenient one for their purpose.

When the stem in Fahrenheit's hydrometer is long, the weight put in the dish at the top, will sometimes render the instrument unsteady, and liable to be very easily overset. This should be provided against by making of a sufficient length the stem to which the counterpoise is attached; the same disadvantage has also been provided against, by giving the instrument two dishes for the reception of weights, one of which, for the larger weights, is situated considerably lower than the

other. A very slender stem is to be preferred, as it exerts less attraction and repulsion than a thick one, and it should always be wiped clean with a linen cloth before the instrument is used.

Hydrometers are employed which are still more simple, but at the same time more imperfect, than either of the preceding: they consist only of a set of glass bubbles, varying from each other in specific gravity at an equal rate, and extending to all degrees required above and below a certain standard. If one of these bubbles be put into any liquid, and is observed either to swim or to sink in it, another is tried, until at length one is found, which has no disposition either to sink or swim, but which will remain at rest in any part of the fluid: this bubble is of the same specific gravity as the fluid itself; and as the strength of the liquor corresponding to it in specific gravity is marked upon it, the operation is finished. The use of these hydrometers is nearly confined to the trying of spirits; for most other purposes, the set must be so numerous that they would be very inconvenient.

General Remarks on taking Specific Gravities.

As all bodies vary in their dimensions with a change in their temperature, it follows that they will not at all times have the same specific gravity, and if no regard be paid to this circumstance, results differing more or less will certainly be obtained. Extensive dealers in spirits have taken the precaution of purchasing only in very cold weather, when the bulk of that liquid is at the least, and of selling chiefly in summer, when its bulk is greatest. It has been found by experiment, that the fifth decimal figure changes at almost every degree of Fahrenheit's thermometer. Philosophers are therefore accustomed to note the temperature at which they operate, or, which is still better, they obtain a temperature of which experience has confirmed the general advantage. For this purpose, 60 degrees of Fahrenheit appears most entitled to regard, as having been the most commonly used, and the most usual in apartments. The water used may be brought to this temperature by additions of the same fluid in a warm or cold state, and the body to be weighed in it should be exposed for a sufficient time in an apartment or atmosphere heated in the same degree. Fluids in a phial may be warmed by grasping the phial in the hand for a short time, and small solids may have their temperature raised in a similar manner.

In taking specific gravities, when water is used or mentioned, it is meant, not only that it should be distilled or rain-water, but that it should be free from all impurities.

When solids are weighed in water, they should be freed from the air-bubbles adhering to them, and should be without crevices, in order that the water may have free access to their surfaces in all directions.

When a varnish of any kind is laid over a substance, to prevent it from absorbing water, some allowance should be made for such addition, unless, besides its being exceedingly thin, it agrees nearly in specific gravity with that of the substance it covers.

Table of Specific Gravities.

A correct table of specific gravities would be a valuable present to the public; but the discordance among such at present existing as embrace a great variety of bodies, is very considerable. This has arisen, sometimes from the variable nature of the substances enumerated; sometimes because the results have been taken by different persons, at different temperatures, and sometimes from the different degrees of correctness in the balances used. Under these circumstances, all that can be done, is, to state the result which has the best and most numerous authorities in its favour, and when different specimens of the same substance are, independent of all errors in weighing, evidently different in their specific gravity, to state the extremes, at one of which, or between them, the specific gravity of any specimen has always been found.

By means of a table of specific gravities, the real weight of a body mentioned in it, may be ascertained without weighing it, provided its dimensions are known, and the real weight of a given bulk of any substance in the table is also known. For example, a cubic inch of water, at the temperature of 60 degrees, weighs 252.576 grains troy; therefore multiply 252.576 by the number of cubic inches in the body whose weight is to be estimated, and that product multiplied by the specific gravity of the body, will give the weight desired. Thus if it be required to know the weight of forty cubic inches of beech wood, $252.576 \times 40 = 10103.040$, and this number multiplied by 0.852, the specific gravity of beech wood, $= 8607.790080$, the weight of 40 cubic inches of beech wood in grains, which may easily be reduced to any other denomination.

Platina, the first article enumerated in the following table, is the heaviest body known to exist; and has deprived gold of the first rank in point of weight, which, previous to the discovery of this metal, about the middle of last century, had always been considered one of its essential characteristics.

Apprehensions were at one time entertained, that platina might be successfully used to adulterate gold: for if gold wese mixed in certain proportions with platina, which is heavier, and copper, which is lighter than itself, the alloy might have the real size, and therefore the specific gravity of standard gold, and a guinea made of this alloy could not be detected hydrostatically, which would otherwise have been an infallible test; but it has been found that gold alloyed with platina, in any proportion that would serve the purposes of fraud, is so debased in colour, that its impurity is obvious to the eye.

	Spec. Grav.
Platina, in grains, as it comes from the mine,	15.600 to 17.200
purified and forged	20.336
laminated by passing through rollers	22.069
Gold, pure, cast but not hammered	19.258
hammered	19.362
of the English guinea	17.629
Mercury, at 30 degrees of heat,	13.619
at 60 ditto	13.580
at 212 ditto	13.375
Silver, pure, cast	10.474
hammered	10.511
standard, containing 11 oz. 2 dwt. of pure silver in the pound troy, after fusion	10.200
Lead	11.352 to 11.445
Bismuth	9.756 to 9.822
Nickel, the purest	7.000 to 9.000
sulphurated	6.620
Copper, cast	7.788 to 8.878
Brass varies with the proportions of its component parts, from	7.600 to 8.800
Iron, cast	7.207
bar	7.788
Steel, soft and not hammered	7.833
hardened in water	7.816
Cobalt, in the metallic state, cast	7.645 to 7.811
Tin, purest Cornish, cast	7.170 to 7.291
hammered	7.299
Malacca, cast	7.296
hammered	7.306
Zinc, cast	7.190
Manganese, in a metallic state	6.850 to 6.990
Antimony, in a metallic state	6.624 to 6.860
Arsenic, in the metallic state	8.310

	Spec. Grav.
Tungsten, of a gray colour	5.800 to 6.028
of a brown colour	5 570
in a metallic state	17.600
Tellurium	6.115
Molybdena	7.500 to 8.600
Titanite	4.180
Manachanite	4.427
Zircon earth	4.416
Ruby, oriental	4.283
Brazilian	3.531
Chrysolite	3.340 to 4.410
Topaz, oriental	4.011
Brazilian	3.536
from Saxony	3.564
Garnet, oriental, carbuncle	4000 to 4.188
common	3.800
volcanic	2.468
Aërated barytes	4.300 to 4.338
Baroselenite	4.400 to 4.865
Corundum stone, or adamantine spar	3.876 to 4.166
Strontian earth	3.400 to 3.644
Diamond, oriental, colourless	3.521
rose-coloured	3.531
orange-coloured	3.550
green-coloured	3.523
blue-coloured	3.525
Brazilian	3.444
Sapphire, oriental	3.991
Brazilian	3.130
Hyacinth	3.687
Granites	2.538 to 2.956
Foilated limestone	2.710 to 2.837
Compact limestone	1.386 to 2.720
Chalk	2.315 to 2.657
Rock crystal, colourless	2.650
rose-coloured	2.670
Quartz	2.640 to 2.670
Amethyst	2.655
Emerald	2.775
Beryl	2.650 to 2.722
Icelandic agate	2.348
Rubellite, or red schorl of Siberia	3.100
Schorl	2.920 to 3.212
Schorlite	3.530

	Spec. Grav.
Tourmalin	3.050 to 3.155
Lapis Lazuli	2.760 to 2.945
Opal	1.700 to 2.118
Chalcedony	2.600 to 2.665
Carnelion	2.597 to 2.630
Flint	2.580 to 2.630
Hornstone	2.530 to 2.653
Jasper	2.500 to 2.820
Egyptian pebble	. 2.564
Heliotropium	2.620 to 2.700
Woodstone	2.045 to 2.675
Feldspar	2.437 to 2.600
Labrador stone	2.670 to 2.692
Agates	2.580 to 2.666
Common spar	2.693 to 2.778
Marble	. 2.700
Gypsum	2.167 to 2.311
Talc	2.700 to 2.800
Indurated steatites, before it has imbibed water	. 2.583
after imbibing water	. 2.632
Basaltes, from the Giant's Causeway	. 2.864
Pumice stone	. 0.914
Asphaltum, cohesive	1.450 to 2.060
compact	1.070 to 1.165
Plumbago (black lead)	1.987 to 2.089
Sulphur, native	. 2.033
fused	. 1.990
Pit-coal	1.400 to 1.550
Mineral tallow	. 0.770
Amber	1.078 to 1.080
Glass, white flint, English	3.290 to 3.300
for achromatic telescopes	. 3.437
crown	. 2.520
common plate	. 2.760
yellow plate	. 2.520
white, or crystal, of France	. 2.892
Porcelain, China	. 2.384
Sieves	. 2.145
from Saxony	. 2.493
Copal	1.045 to 1.061
Ambergris	0.780 to 0.926
Phosphorus	. 1.714
Common Rosin	. 1.072
Sandarac	. 1.092

	Spec. Grav.
Mastic	1.074
Storax	1.109
Elemi	1.018
Gum lac	1.139
Caoutchouc, or Indian rubber	0.933
Camphor	0.988
Gum Ammoniac	1.207
Myrrh	1.360
Gamboge	1.221
Gum Arabic	1.452
tragacanth	1.316
Inspissated juice of liquorice	1.722
Opium	1.336
Indigo	0.769
Arnotto	0.595
Bees' wax, yellow	0.965
white	0.968
Spermaceti	0.943
Honey	1.450
Fat of beef, veal, mutton, &c.	0923 to 0.948
Tallow	.942
Dry ivory	1.825
Wood, heart of oak, 60 years old	1.170
Dry oak	0.925
Ebony	1.117
Trunk of elm	0.671
ash	0.845
Beech	0.852
Alder	0.800
Maple	0.755
Walnut	0.671
Willow	0.585
Fir	0498 to 0.550
Poplar	0.383
White Spanish poplar	0.529
Apple-tree	0.661
Plum-tree	0.705
Cherry-tree	0.715
Filbert-tree	0.600
Box, French	0.912
Dutch	1.328
Yew-tree, Dutch	0.788
Spanish	0.807
American cedar	0.560
Lignum vitæ	1.333

	Spec. Grav.
Red Brazilwood	1.031
Logwood	0.913
Corkwood	0.240
Distilled, or rain-water, at 60° Fahrenheit	1.000
Sea-water	1.026
Water of the Dead sea	1.240
Naphtha	0.847
Petroleum	0.878
Acid, sulphuric	1.841 to 2.125
nitric	1.272 to 1.580
muriatic	1.194
acetous, red	1.025
white	1.014
distilled	1.010
acetic	1.063
Spirits, or volatile oil of turpentine	0.870
lavender	0.894
cloves	1.036
cinnamon	1.044
Oil of olives	0.915
sweet almonds	0.917
linseed	0.940
poppy-seed	0.929
whales	0.923
Milk, human	1.020
mare's	1.035
ass's	1.036
goat's	1.034
ewe's	1.041
cow's	1.033
Human blood	1.054
Alcohol, or pure spirit, at 60° Fahrenheit	0.813
Proof-spirit, according to the excise laws	0.916
Ether, sulphuric	0.7396
nitric	0.9088
muriatic	0.7296
acetic	0.8664
Common air, when the barometer is at 29⅞, and thermometer at 60°	0.001220
Azotic gas	0.001146
Oxygen gas	0.001305
Hydrogen gas	0.000091
Carbonic acid gas	0.001682

Specific Gravities of Mixtures of Spirit and Distilled Water, at the temperature of* 608.

Spirit (grains)		Water (grains)		Spec. Grav.
100 grains of spirit to		5 grains of water,		0.83599
100	..	10	..	0.84568
100	..	15	..	0.85430
100	..	20	..	0.86208
100	..	25	..	0 86918
100	..	30	..	0.87568
100	..	35	..	0.88169
100	..	40	..	0.88720
100	..	45	..	0.89232
100	..	50	..	0.89707
100	..	55	..	0.90144
100	..	60	..	0.90549
100	..	65	..	0.90927
100	..	70	..	0.91287
100	..	75	..	0.91622
100	..	80	..	0.91933
100	..	85	..	0.92225
100	..	90	..	0.92499
100	..	95	..	0.92758
100	..	100	..	0.93002
95	..	100	..	0.93247
90	..	100	..	0.93493
85	..	100	..	0.93749
80	..	100	..	0.94018
75	..	100	..	0.94296
70	..	100	..	0.94579
65	..	100	..	0.94876
60	..	100	..	0.95181
55	..	100	..	0.95493
50	..	100	..	0.95804
45	..	100	..	0.96122
40	..	100	..	0.96437
35	..	100	..	0.96752
30	..	100	..	0.97074
25	..	100	..	0.97409

* The results in this table were obtained with spirit, the specific gravity of which was 0.825, as it was found difficult to obtain, of greater purity, the quantity required.—Vide Gilpin's tables, Philos. Trans. for 1790, 1792, and 1794.

					Spec. Grav.
20 grains of spirit	to	100	grains of	water,	0.97771
15	..	100	..	..	0.98176
10	..	100	..	..	0.98654
5	..	140	..	..	0.99244

Of the Diving Bell.

The nature of the diving-bell may easily be understood, by reflecting on the facility with which air may be retained under water, in vessels open only at the bottom, because air, like any solid, prevents other bodies from occupying the place it occupies itself. Thus if we take a glass tumbler, or any similar vessel, and holding it inverted, push it vertically downwards into water, the air it contains will not escape, and the water, at inconsiderable depths, will scarcely rise at all within it. It is clear, that whatever were the size of the vessel, the water would in the same manner be excluded by the air; and as the air is the same as that of the atmosphere, it is equally clear, that in a vessel of sufficient size, men might be stationed without being incommoded by the water, as they could breathe the air and live till its vital principle was exhausted. If, then, any means were contrived to remove the contaminated air, and to send down a supply of fresh, they might remain under water as long as they chose, and if let down by a rope, to a wreck or to the bottom of the sea, they might perform any work of which the size of the vessel admitted, or to which they were competent on land. The vessel used for this purpose, is called a bell, because it is made in the form of a truncated cone, and often resembles a bell in its general appearance. It must be mentioned, however, that the water, in proportion to the depth to which the bell is sunk, rises within it, by the increase of its pressure, and compresses the air. The reader will recollect, that a column of water about thirty-three feet high, is equal to the pressure of the atmosphere; at the depth, therefore, of thirty-three feet under water, the water presses into the bell with the power of a double atmosphere; and the air, which when it was at or very near the top, occupied the whole interior capacity, does not then occupy more than half of it, consequently the bell becomes half full of water; and at all greater depths the air sustains a proportionately greater compression, the water at the same time rising as this effect goes on, till at length it almost covers the divers.

Dr. Halley was the first person who materially improved the diving-bell. He formed of copper, a machine of this kind, in the form of a common bell; and weights of lead were distributed about the lower part, to keep it in an inverted position, while they rendered it at the same time specifically heavier than its bulk of water, and consequently it would sink by its own weight. It was three feet wide at the top, five feet wide at the bottom, and eight feet high. In the top was a window made of very thick glass, and also a stop-cock, to let out the hot air which had been breathed; and, within the bell was a circular seat for the divers. This machine was let down into the sea from the yard-arm of a ship, with two men in it, to the depth of ten fathoms. To supply the divers with air, two barrels, of about 63 gallons each, cased with a sufficient quantity of lead to make them sink, were alternately sent down to them. The bung-hole in each barrel was left open, and kept on the under side, to let in the water as the air in the barrels condensed during their descent, and to let the water out again when they were drawn up. To a hole in the upper side of the barrels, was fixed a leathern pipe, well prepared with bees' wax and oil, which was long enough to fall below the bung-hole at the bottom, and kept down by a weight in such a way that the air in the upper part of the barrels could not escape, unless the lower ends of these pipes were first lifted up. These air-barrels, by means of proper tackle, were made to rise and fall in succession, like two buckets in a well; in their descent, they were directed to the divers by ropes fastened to the under edge of the bell, and one person held himself always in readiness to receive them, and by taking up the ends of the pipes above the surface of the water in the bell, the water by its pressure filled the barrels, while the air they contained rushed into the upper part of the bell. As soon as one barrel was discharged, at a signal given, it was drawn up, and another sent down; thus a continual supply of fresh air was afforded to the divers, with so much ease, that two men on board the ship, could with less than half their strength, perform all the labour required. Meanwhile, as the cold air rushed from the barrel into the bell, it expelled the hot air at the top, where the stop-cock was opened for that purpose. Dr. Halley was himself one of five, who went down together in his bell; they remained at the bottom, in a depth of nine or ten fathoms, for an hour and a half, without experiencing any ill effects, and might have continued any length of time that they had wished. The window in the top of this bell let in so much light, that when the sun shone, and the sea was unruffled, they could read or write with great ease, and could see the pebbles, or take up

any small objects that happened to be at the bottom; but every thing they saw appeared red, because as the red rays alone have power to penetrate through such a body of water, the objects below could reflect no other. By writing with a piece of sharpened iron upon small pieces of lead, which they sent up with the returning air-barrel, they maintained a communication with those above, and directed the bell to be moved as they desired. In misty weather, and when the sea was rough, it was nearly dark in the bell, and it then became necessary to burn a candle, which consumed as much air as one person. The divers, in descending with this bell, and the case is the same with any other, felt a pain in their ears, as if the end of a quill had been thrust into them. This sensation was owing to the pressure of the condensed air upon the tympanum; it went off gradually as the air in their bodies became as dense as that without.—It appears by this account, that the pressure of a double or even threefold atmosphere is much more endurable, than the diminution of the ordinary pressure to half a single atmosphere.

Dr. Halley contrived a method of sending a man out of the bell to some distance, by means of a small bell upon his head, with a glass in front, and a flexible pipe communicating with the great bell, to convey to him a regular supply of fresh air.

Triewald invented a diving-bell of a different form, which was much smaller, and less expensive, than Dr. Halley's; it only covered half the body of the diver, who stood upon a ring hanging from the bell by chains. There was also a spiral pipe within the bell, by which he could always breathe the air immediately at the surface of the water in the bell, where it was cooler and fresher than at the upper part of the machine.

Smeaton's diving-bell was a chest of cast iron, 4½ feet in height, 4½ feet in length, and three feet wide. It was intended for two men to work in, had four strong glass lights at the top, and was supplied with fresh air by a forcing-pump. It was used with great success at Ramsgate.

A. Walker, contrived a diving-bell, supplied with air by a forcing-pump like Smeaton's, and constructed at a very small expense. It consisted of a conical tub of wood, three feet diameter at the bottom, two feet and a half at the top, and three feet high. It was so loaded with lead at the bottom as just to sink in water, and had one small seat for a single diver. The forcing air-pump furnished a continual supply of fresh air, and the vitiated air was forced out at the bottom. With this bell over him, the diver could walk about, and have an easier access to the objects of his research, than in the usual cumbersome structure. The greatest part of the wreck saved

from the rich ship Belgioso was taken up by means of this diving-bell.

For descending to small depths, diving-bells have been contrived, which have been merely a case for the body, to keep off the pressure of the water from the trunk, while the limbs were uncovered. They were supplied with fresh air by pipes extending to the surface. One of this description is described in the eighth volume of the Philosophical Magazine.

The diving-bell of which we shall give a representation, is that invented by Spalding, of Edinburgh. It is a very ingenious contrivance, and was intended to obviate the inconveniences which attach to Dr. Halley's bell, and, more or less, to most others. 1. In Dr. Halley's construction, the sinking or rising of the bell depends on the people who are at the surface of the water; and as the bell when in the water has a very considerable weight, the raising of it not only requires a great deal of labour, but if, by any mischance, the rope by which it is raised should break, every person in the bell would perish. 2. As there are, in many parts of the sea, rocks which lie at a considerable depth, the figure of which cannot possibly be perceived from above, some prominence may catch hold of the edge of the bell in its descent, and thus overset it before any signal can be given to those above; this accident would also be destructive to the divers; and as it must always be unknown before trial, what kind of a bottom the sea has in any place, it is plain, that without some contrivance to obviate this last danger, the use of Halley's bell is attended with a considerable risk. The contrivance intended to remedy these inconveniences, is shewn at fig. 1. pl. II. ABCD represents a section of the bell, which is made of wood; *e e* are iron hooks, by means of which it is suspended by ropes, QBF *e*, QAE, *e*, and QS; *c c* are iron hooks, to which are appended leaden weights, that keep the mouth of the bell always parallel to the surface of the water, whether the machine, taken altogether, is lighter or heavier than an equal bulk of water. By these weights alone, however, the bell would not sink, another is therefore added, represented at L, and which can be raised or lowered at pleasure, by means of a rope passing over the pulley *a*, and fastened to the sides of the bell M. As the bell descends, this weight, called by the Inventor the balance-weight, hangs down at a considerable distance, below the mouth of the bell. In case the edge of the bell is caught by any obstacle, the balance weight is immediately lowered, so that it may rest upon the bottom; by this means the bell is lightened, so that

all danger of oversetting is removed; for being lighter, without the balance-weight, than an equal bulk of water, it is evident that the bell will rise as far as the length of the rope affixed to the balance-weight will allow it. This weight will therefore serve as a kind of anchor, to keep the bell at any particular depth which the divers may think necessary, or by pulling it quite up, the descent may be continued to the very bottom: these facilities of management are of great moment.

This bell included another contrivance, by which the divers were enabled to raise the bell with all the weights appended to it, even to the surface, or to stop at any particular depth; and thus they could still be safe, even though the rope designed to pull up the bell should break. For this purpose, the bell is divided into two cavities, both of which are made as tight as possible; just above the second bottom, EF, are small slits on the sides of the bell, through which the water entering as the bell descends, displaces the air originally contained in its cavity, which flies out at the upper orifice of the cock H. When this is done, the divers turn the handle which stops the cock, so that if any more air was to get into the cavity AEFB, it could no longer be discharged through the orifice H as before. When this cavity is full of water, the bell sinks; but when a considerable quantity of air is admitted, it rises. If therefore the divers determine to raise themselves, they turn the small cock, by which a communication is made between the upper and under cavities of the bell; the consequence of this is, that a quantity of air immediately enters the upper cavity, forces out a quantity of water contained in it, and thus renders the bell lighter by the whole weight of the water which is thus displaced. If a certain quantity of air is admitted into the upper cavity, the bell will descend very slowly; if a greater quantity, it will neither ascend nor descend, but remain stationary; and if a larger quantity of air be still admitted, it will rise to the top. It is to be observed, however, that the air which is thus let out into the upper cavity, must be immediately replaced from the air-barrel, and the air is to be let out very slowly, or the bell will rise to the surface with such velocity that the divers may be shaken out of their seats; but with due care, every possible accident may be prevented, and people may descend to very great depths without the least apprehension of danger; the bell also becomes so easily manageable in the water, that it may be conducted from one place to another by a small boat with great ease, and with perfect safety to those who are in it. There are two windows

made of thick glass, for admitting light to the divers; and instead of wooden seats, used by Dr. Halley and others, ropes are suspended by hooks *b b b*, and on these ropes the divers may sit without any inconvenience. N represents an air-cask with its tackle, and CP the flexible pipe through which the air is admitted to the bell; in the ascent and descent of this cask, the pipe is kept down by a small weight, as in Dr. Halley's machine. R is a small cock, by which the hot air may at any time be discharged. When the bell is to be used, it is conveyed to the place required, by means of two boats or barges, connected together by cross-beams at stem and stern, and with a sufficient space between them to admit the bell. From the top of an angular framing, one side of which goes into each boat, descends the rope that supports the bell, which is raised or lowered by a windlass in each boat. When the divers wish to come up, they give a signal for that purpose, and the windlasses are turned till the bottom of the bell is at some distance above water; a small boat or raft is then rowed under them, and they get out: they get in the same way, and in both cases without being wet, or suffering any other inconvenience. The signals consist in ringing bells attached to the windlass frame, from which strings descend into the bell.

The main rope by which a diving-bell is supported, ought to be soaked in water before it is used; or it would perhaps be still better if a chain were substituted. An instance occurred in the bay of Dublin, where the rope, in suffering the contraction which water always occasions, caused a diving-bell to turn round, by which means the signal-strings were entangled. The people above, not receiving the signals they expected, drew up the bell: but they were too late; the two men it contained were both dead; not drowned, but suffocated by the want of a supply of fresh air.

Another circumstance proper to be attended to in using a diving-bell, is to lower it very gradually through the water; to prevent the injurious effects which the abrupt condensation of the air contained in it might have upon the men.

OF HYDRAULICS.

We have now to consider the objects of Hydraulics, which, it has already been explained, relate to the laws and uses of fluids in motion. Here, as in Hydrostatics, though the doctrine laid down might be applied to fluids in general, allowing for differences in density, yet water is the fluid constantly referred to; because it is the fluid with which men are most extensively concerned, and elucidations specifically applied give greater precision to the subject.

Of the Motion of Water flowing out of reservoirs.

When a vessel, containing water, and open at the top, is pierced below the surface of the fluid, the velocity with which the water flows out is observed to be greatest at first, and to diminish gradually as the water sinks, and the nearer the aperture is to the bottom, the greater the quantity which flows out in a given time. From a hole on a level with the bottom of the vessel, the water would immerge with nearly the same velocity as if it were in the bottom. This egress of fluids from the perforated sides of vessels, is a consequence and a proof of their pressing in every direction; and the law which governs the rate of it is an admirable illustration of the harmony which distinguishes the operations of nature, although our limited powers are but occasionally competent to its development: *the velocity with which water flows out of an aperture at the side or bottom of a vessel, is as the square root of the distance of the aperture from the surface of the water.* This is but saying, in other words, that the velocity is according to the pressure or force which occasions it, and it has already been demonstrated that the pressures of fluids is as their perpendicular heights. Hence it is deducible, *that the velocity with which water flows from an aperture, is the same as that which would be acquired by a body in falling from a height equal to that between the surface and the aperture.* In order, therefore, that double the quantity of water may flow through one hole that flows through another of the same size, the former must be four times as far from the surface as the latter; and if a supply of three times the quantity of water be required, without changing the size of the aperture, three times the velocity must be produced, and three times the velocity will require nine times the pressure, consequently the hole must be nine times as far from the surface of

the fluid, as that which only produced a third of the supply. An experiment in proof of these positions, is easily made: let two equal pipes be fixed into the side of a vessel containing water, but one of them at four times the distance of the other from the surface: let the two pipes be allowed to run at the same moment, while water is constantly poured into the vessel, and kept at the same height in it during the experiment. Then if a cup that holds a pint, be so placed as to receive the water that spouts from the upper pipe; and at the same time, a cup that holds a quart, be placed to receive the water from the lower pipe, both cups will become full at the same moment.

The horizontal distance to which a fluid will spout from an aperture, in any part of the side of a vessel, below the surface of the fluid, is equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe to a semicircle described upon the altitude of the fluid; and therefore the distance will be the greatest possible, when the mouth of the pipe is at the centre of the semicircle; because a perpendicular to its diameter (supposed parallel to the side of the vessel) drawn from that point, is the longest that can possibly be drawn from any part of the diameter to the circumference of the semicircle. Thus, in fig. 2, pl. II, from the point E, at the middle of a vessel represented by RS, and filled with water, draw a semicircle, A *e* B, the diameter of which is equal to the height of the vessel; from H, E, and I, where the side of the vessel is perforated, draw lines parallel to the horizon till they reach the semicircle, as I *i*, E *e*, and H *h*. Now if the water in the vessel be kept constantly at the same height, the jet which issues from the aperture I, will describe (nearly) a parabolic curve, and fall upon a horizontal line on a level with the bottom of the vessel at L, and LA will be found equal to twice the distance I *i*; and as the line H *h* is the same length as I *i*, the jet from H will also fall at L. Still obeying the same rule, the jet from E will be the greatest possible, as it will reach to twice the horizontal distance E *e*, that is, to P. The horizontal range of the jet, in each case, as AL, is called the *amplitude* of the jet. The curve described by these jets is the same as that described by a cannon-ball in its flight, or any other solid projectile; it is compounded of the rectilinear motion produced by the lateral pressure of the fluid, and the accelerating effect of gravitation in changing its horizontal course; it will not therefore be precisely that curve called a parabola, except in vacuo, or a non-resisting medium; but when the height of the vessel is inconsiderable, the amount of the deviation from a parabola is not material.

If the vessel RS, fig. 2, have an aperture so contrived that the jet forced out of it shall be directed upwards perpendicularly as by a pipe M, the jet will never reach the altitude of the head of water or column forcing it out, because the action of the atmosphere causes it to spread, and at length divides it into drops. A great variety of circumstances regulate the action of fluids flowing in this manner. For example, a jet will not rise so high from the tube, as if it rose by the impulsion of a similar column in the manner shewn by fig. 3. If the pipe M, fig. 2, were inclined a little, the jet would rise somewhat higher, because no part of the water would then fall back in the direction in which it came, and thus impede the motion of the rising stream. If the pipe M, from the vessel RS, be of considerable length, the jet discharged from it will not be so great as when it is short; and if its diameter be the same as its aperture, the jet will also be less than if the diameter of the conduit-pipe much exceed that of the aperture; the reason is, that when the conduit-pipe is large in proportion to the aperture, the motion of the water in it is slow, and therefore it has less friction. A conical pipe will not afford so large a jet as a cylindrical pipe, ending with a flat surface, with the hole in the middle of it. By enlarging the aperture of a jet, the friction against the sides is proportionately diminished; but the thicker the column, the greater the resistance of the air. There must, therefore, be some particular diameter for a jet, at which the resistance of the air and the friction will be such, as to produce a maximum effect; this is found to take place when the diameter of the aperture is somewhat less than an inch and a quarter. If the aperture be larger or less than this, the jet will not rise so high. The higher the reservoir, within certain limits, the nearer the summit of the jet approaches to the level of the head of water; but no jet can rise higher than 100 feet, let the height of the head of water be what it may. Theory, on these subjects, is exceedingly apt to be erroneous, by not comprehending all the modifying circumstances; and there is yet a wide field for useful experiment: the following table has been deduced from experiments to ascertain the height to which jets of water will rise perpendicularly, when the altitudes of the water in the reservoir are from 5 to 100 feet:

Depth of the reservoir.	Height of the jet.	Depth of the reservoir.	Height of the jet.	Depth of the reservoir.	Height of the jet.
5	4.91	9	8.74	16	15.22
6	5.88	10	9.68	18	17.03
7	6.84	12	11.55	20	18.82
8	7.80	14	13.40	22	20.58

Depth of the reservoir.	Height of the jet.	Depth of the reservoir.	Height of the jet.	Depth of the reservoir.	Height of the jet.
24	22.33	50	43.65	76	62.84
26	24.06	52	45.19	78	64.24
28	25.78	54	46.72	80	65.64
30	27.48	56	48.24	82	67.02
32	29.16	58	49.74	84	68.40
34	30.83	60	51.24	86	69.76
36	32.47	62	52.73	88	71.14
38	34.11	64	54.20	90	72.48
40	35.74	66	55.66	92	73.82
42	37.35	68	57.12	94	75.16
44	38.93	70	58.56	96	76.49
46	40.53	72	60.00	98	77.81
48	42.09	74	61.42	100	79.12

When water spouts from the side or bottom of a vessel which is very thin, and the aperture is at the same time very small when compared with the size of the vessel, the stream is observed to be narrower at a short distance from the vessel than in any other part, and less even than the size of the aperture. This will be observed on inspecting the jets H, E, and I, fig. 2, close to the vessel. This narrow part of the stream is called the *vena contracta*, or *contracted vein*. When the aperture is circular, its distance from the interior of the vessel is about equal to the diameter of the aperture; when, therefore, the thickness of the side of the vessel exceeds or is nearly equal to the diameter, this contraction is not perceived. The diameter of the *vena contracta* varies a little with the form of the aperture, the thickness of the vessel, and other circumstances not easily detected; but in general it is equal only to about four-fifths of the aperture. As the particles of a fluid above an aperture run from every part to make their egress there, it is evident that those which come from a part situated obliquely to the axis of the aperture, will have a tendency to converge; and though this tendency is materially checked by the opposition of the fluid from other parts, it yet has the effect of producing the *vena contracta;* and afterwards, partly like the effect of the crossing of rays which have met in a focus, it occasions, independently of the concurring effect of the atmosphere, the water to spread the farther it recedes from that place. When the aperture bears a considerable proportion to the size of the vessel, the *vena contracta* is not observable.

It is laid down as a principle, that the velocity with which water spouts from an aperture, is not equal to that acquired

by a body falling perpendicularly from a height equal to the distance between the surface of the fluid and the centre of the aperture; but it must be explained, that this velocity is not acquired by the fluid, till it has reached the *vena contracta*; for precisely at the aperture, supposing the vessel to be exceedingly thin, the velocity of the water is found by experiments to be only half that which a body would acquire in falling from a height equal to the depth of the fluid. But as the *vena contracta* generally coincides with some part of the aperture, on account of the thickness of vessels, these distinctions are not noticed in practice.

When a pipe is adapted to any part of the vessel, as a passage for water, it is, whatever its figure or size, called an *adjutage*. The effect of an adjutage varies with its figure and length; but its general effect is to increase the discharge of water, unless its shape be conical throughout, with its base at the reservoir, in which case the discharge is less than that of a simple aperture; if the conical adjutage be continued by a cylindrical tube, the discharge will be still further diminished, in proportion to the length of this tube; but if an adjutage be in the first instance conical, as in fig. 4, plate II, so that the narrow part *a*, shall just correspond in situation and diameter to the *vena contracta* of an aperture *e*, while from *a* to *b* the tube is expanded as a jet is naturally disposed to do, the quantity discharged in a given time will be two and a half times greater than if the pipe were throughout cylindrical, of the diameter at *a*. When an adjutage projects into the interior of a reservoir, the discharge from it is reduced nearly one-half.

Where the head of water is not constantly maintained in a reservoir, or when no supply is received during the discharge from the adjutage, the quantity discharged will only be one-half of what it would be if the level were always preserved.

It may be useful to observe, that the discharge of water running out of the bottom of a cistern, through a descending pipe, is nearly the same as if the cistern were continued through the whole height, from the surface of the water to the orifice of the pipe, and the water were then discharged from the bottom of this cistern by a short pipe in any direction. Some doubts as to the truth of this proposition having been entertained, although it rested on the authority of the best writers on hydraulics, it was scrutinized by an experiment tried at the Royal Institution. A tube was fixed horizontally in the bottom of a vessel, and water was poured through another tube of similar dimensions placed vertically, and it was

found that more water passed through the latter tube than the horizontal one could carry off.

The progress of water through a pipe, is greatly retarded by every deviation from a rectilinear direction, and by every enlargement, contraction, projection, or roughness it meets with in its passage; and most of these irregularities are of too variable and uncertain a nature to be submitted to regular calculation. They operate in occasioning eddies or contrary currents, in counteracting which, part of the moving force is inevitably lost. To avoid, as much as possible, the retardation from flexure, when it is necessary to give a new direction to a pipe, the point of flexure should not be sharp, but take as comprehensive a sweep as can be allowed.

Of the Motion of Water in Rivers, and of Waves.

The motion of a river is in general produced by the descent of the water from a higher to a lower situation; and therefore it is swift or slow according as the descent or inclination of the bed of the river is great or small. Sometimes, or in some parts of rivers, the motion is produced by pressure, or disposition of the water to spread itself out, in which case it increases with the depth.

To ascertain whether the water of a river, almost horizontal, flows by means of the velocity acquired in its descent, or by the pressure of its depth, set up an obstacle perpendicularly in it, then if the water rise and swell immediately against the obstacle, it is the descent which occasions its motion; but if it first stop a little it is impelled by pressure.

The velocity of running water, in different parts of the same section, is very different, yet it is often desirable to ascertain its mean amount, when it is intended to apply it to machinery. Watt found that in a canal 18 feet wide above, and 7 below, and 4 feet deep, with a fall of four inches in a mile, the velocity was 17 inches in a second at the surface, 14 in the middle, and 10 at the bottom, so that the mean velocity may be called 14 inches, or somewhat less, in a second. To find the velocity at the surface is easy, by observing, in calm weather, the rate at which a body flows when just immersed in it; but the velocity at any considerable depth, is not obtained with the same facility. One of the best methods is the use of an instrument, consisting of a tube, at one end of which, and at right angles to its length, is affixed a funnel. This funnel being presented to the stream, and the tube held vertically, the water rises in the tube above the surface of the river to a height corresponding to the velocity. If the funnel be covered with a plate, having a small hole in its centre, the elevation of the water will

exceed what is due to the velocity by nearly one-half. A very simple mode of ascertaining the mean velocity of a stream, consists in the use of a pole of light wood, about the same length as the depth of the stream; the lower end of this pole is loaded, so that, in still water, it would remain in a vertical position, with its upper end near the surface; the preparation of it is finished, by fixing in the upper end, exactly in the direction of its axis, a slender rod to project above the water. This pole being placed in a river, the rod will point up or down, according as the stream is swiftest at the surface or near the bed, and the rate of its motion, in any given space of time, will be the mean velocity at that place. By thus taking the mean velocity, at various places between opposite points of the banks, and dividing the sum of all the velocities by the number of trials, a mean will be obtained sufficiently correct for practice. In cases where an estimate may be thought sufficiently accurate, the medium velocity may be taken at nine-tenths of the superficial.

The windings of the banks and inequalities of the beds of rivers, destroy a large proportion of the velocity which would otherwise be generated. The Ganges, by its windings has the declivity of its bed reduced to less than four inches per mile, and the medium rate of its motion is rather less than three miles an hour: this is in the dry months, when its medium depth is 30 feet. Of the Po, the medium depth of which river is 29 feet, and the fall 6 inches in a mile, the velocity is 3¼ miles in an hour. The velocity of a river ought to accumulate with the length of its course; but the causes of retardation are often sufficiently powerful to produce a contrary effect. One part of a river is generally observed to flow with much greater velocity than any other part, and is therefore called the *thread* or *channel of the river*, which is very rarely in the middle, or at any regular distance from the banks, but is more or less inclined to one of them, according to their form; and their form, with that of the bed, is often an accidental contingent of differences in their texture, which cause them to resist or yield to attrition. When a river changes the direction of its course, the velocity is greater on the concave than the convex side of the flexure.

The waves formed on water by the action of the wind, are superficial oscillations of the fluid, that are by no means so irregular in their action as might be inferred. When water is at rest in a bent tube, like that represented by fig. 5, pl. I, if one aperture be blown into, the water rises above its level in the other, and makes a few vibrations before it subsides. The times employed in performing these

vibrations are all equal, for equal columns, whether the vibrations themselves be long or short with respect to the space over which they move; and they are the same as the time in which a pendulum, the length of which is equal to half the length of the fluid, performs its cycloidal vibrations. The pendulum, it is well known, when drawn out of a perpendicular position, endeavours to regain it; but in doing this it has obtained a velocity which carries it out of the perpendicular on the opposite side; in the same manner, the water in the tube, when raised in one limb, on being left at liberty, overpasses the point where it will rest in the end; the same principle of motion distinguishes waves. The first impression of the wind upon the water, is to produce a cavity; this cavity cannot be produced without heaping up the water before it; the water thus heaped, having attained an elevation proportionate to the force which caused the depression, sinks down towards its level, but in thus sinking down, it acquires a velocity which carries it below its level; by this means it produces a depression like that occasioned by the wind in the first instance, and thus successive waves are propagated, but the motion diminishes in proportion to the distance over which the force extends. The transverse horizontal extent of the base of a wave is called its *breadth*, and it is equal to the space between the most elevated points of two adjoining waves. A wave is said to have performed one vibration, when it has run half its breadth, that is, when the highest part of it has become the lowest; and the time of a vibration is correspondent to that which a pendulum half the length of the space run over in one vibration, would require to perform one of its cycloidal vibrations; therefore a wave will run its whole breadth, in the time of two vibrations of a pendulum equal to one-fourth of the transverse length of that wave's two sides.

The depth to which the sea is agitated, even in violent tempests, is not very considerable; at the depth of twenty feet below what is the level in a calm, the effect is very slight, and at thirty feet it would probably be altogether imperceptible. It may therefore seem difficult to account for the mountainous waves encountered by seamen; but it must be remembered that the wind is constantly acting, and that one wave is raised on the surface of another, till the accumulation becomes prodigious.

When a stone or any other body is thrown into a vessel containing oil, it agitates the surface nearly as much as if thrown into a like quantity of water; but the power of the wind on a surface of oil is exceedingly small, and incapable of producing more than a slight undulation. This fact was first published in modern times, at least, by Dr. Franklin, who intimated the

possibility of applying it to useful purposes, after having observed how thin the pellicle of oil poured out upon water will become, without losing its effect in depriving the wind of its influence. A quantity of oil, in the proportion of half an ounce to an acre, poured out on the windward side of a lake, will spread itself over the whole surface, and still the waves raised by a tempestuous wind. Where the oil cannot be poured out at the place where the waves begin, the effect is less remarkable, because the waves are formed before they reach the oily part of the surface, and therefore they can only be deprived of that addition to their motion which they would otherwise have received while passing over the part which the oil covers. Captains of vessels sometimes use considerable quantities of oil, by pouring it out to diminish a surf; and pearl divers do the same, when they wish to clear the surface of the sea before they go down. It is the various kinds of fat or fixed oils which produce the effects in question; light, volatile, or essential oils, are inefficient.

Of Hydraulic Machines.

The common or sucking Pump.

The common pump, with which water is drawn out of wells, is usually called a *sucking pump*. This appellative originated at a period when the effect was attributed to *suction*, and ought to have been rejected when the pressure of the atmosphere was fully proved to be the efficient agent in causing the water to rise. The mechanism of the common pump is represented by fig. 5, plate II, where the tubes are supposed to be of glass, as the models of pumps shewn by lecturers on hydraulics commonly are, for the purpose of illustrating more clearly the mode in which machinery of this kind operates. At the lower end A, of the pipe AB, is placed a valve *g*, opening upwards; in the piston, E, is placed another valve, *h*, opening upwards like that at *g*. The piston E, fits the pipe so accurately as to be air-tight, and consequently water-tight; yet it is not so fastened but that it may easily be raised or depressed by the rod F, which is connected with it, and wrought by the reciprocating motion of the handle I. The lower pipe K, is open at both ends, and descends into the water of the well. When the pump is first constructed, it is plain that the air between the two valves, and that in the pipe below them, is of the same density as the air of the atmosphere, consequently the water, when the pipe K is put into the well, rises in it but a very little

way, and is at most incapable of rising in the tube above the level of the well, because the air within and that without the tube press upon the water with equal force. Now let the piston E be raised; and the air between the two valves will, in proportion to the length of the stroke, have a larger space to occupy; this increased space it immediately fills by its power of expansion; but as it cannot expand without becoming less dense, and it cannot become less dense, without a diminution of its power of resistance; therefore, as soon as the piston is raised, the superior elasticity of the air contained between the valves *g* and the water, causes this valve to open; by this means the whole column of air between the piston E, and the surface of the water in the pipe K, is rendered less dense than it was before the stroke: on which account it presses on the water at the lower part of the pipe with less force than the air on the outside of it. The external air, therefore, presses the water up the pipe K, until the column of air above the water in this pipe, though shortened by the rising of the water, is of the same density as before, when an equilibrium takes place. All these operations, though tedious to describe, are instantaneously consequent of the stroke made with the handle I; and no sooner is the stroke repeated, than they follow each other over again, and the consequence is, that the water rises still further in the pipe K, till at length it rises above the valve *g*, to the piston E, on depressing which the water passes through the valve *h*, and is discharged at the pipe *m* on raising it again. After the pump has once been wrought, while it remains in order, the water always remains above the piston E, so that the first stroke with the handle, discharges water from the pipe *m*.

The pipe AB is generally called the working barrel, and the pipe K the suction-pipe. At the bottom of the pipe K, the water is admitted by small holes, to prevent the entrance of dirt, weeds, &c. which might injure the mechanism of the working barrel.

Every time the piston E is raised, the valve *h* closes, and every time the piston E falls, the valve *g* closes and *h* rises, which causes the stream flowing from the pipe *m* to be very unequal. But as an equal stream is more agreeable, and often more convenient, it may be obtained by having a cistern at the head of the pump, and making the spout small. By this means the water brought up at successive strokes is emptied first into the cistern, from which it issues at the pipe almost in an equable stream.

As the water rises in a pump by the pressure of the atmosphere, which is removed from the water at the base of the pipe K, while it remains on the rest of the surrounding surface of the

well, it follows that a pump cannot act in vacuo, and also that in any other situation, as there is a limit to the pressure, there is a limit to its effects. The pressure of the atmosphere is variable; when the barometer is at 31 inches, it is, upon any given base, equal to that of a column of water 35 feet high upon a base of the same area; but when the barometer is at 30 inches, it is only equal to a column of water $33\frac{9}{10}$ high: it is in general, however, only considered equal to the pressure of 33 feet of water. It is evident that no force can overcome a greater force than itself; the pressure of the atmosphere, therefore, can, at the most, only raise water to the heights stated; and the allowances to be made for imperfections of workmanship are so considerable, that it is not in practice considered proper to make the length more than 25 feet, or, at the extreme, 30 feet below the moveable valve.

The force required to work a pump, after the water is raised to the moveable valve, varies with the square of the diameter of the working barrel; thus a barrel twice the diameter of another will raise four times the water of the latter, but the working of it will require four times the strength; for the horizontal section of the cylinder is a circle, and the areas of circles are as the squares of their diameters. The size of any part except the working barrel is of no consequence, so far as regards the strength required to work the pump, with the exception that the smaller the pipe K, the greater will be the friction. It has been found, that when the handle increases the power five times, and the diameter of the working barrel is 4 inches, a labouring man, at an ordinary rate of exertion, will discharge 27½ wine gallons per minute.

The velocity of the stroke of a pump should never be less than four inches, nor greater than two or three feet in a second; the stroke should be as long as possible, to prevent loss of water by the frequent alternations of the valves. The diameter of the suction-pipe is best proportioned, when it is from two-thirds to three-fourths of that of the barrel.

The lifting Pump.

The lifting pump is generally used for great water-works, and where the water is not to be brought up from any great depth. It is variously constructed, but in general the upper valve is fixed, and the lower one moveable: and the water is in fact lifted as if it were in a bucket; the sides of the bucket being formed by the barrel, and the piston forming its bottom. Thus in fig. 6, plate II, *a* is the stationary valve, and *b* the moveable one; for it is attached to the piston B, which, when

the pump is at work, is alternately raised and depressed by the rods *d d*, passing through the frame of the valve *a*, and connected with a handle at X, or with a crank if wrought by machinery. Both the valves open upwards as in the common pump. The piston B is forced down into the water, which lifts the valve *b*, and rises to its level in the barrel C; then when the piston B is lifted up, as its valve closes, the water that had gotten above it, cannot re-enter the well, it is therefore lifted at the same time; and as soon as the column of water reaches the stationary valve, it opens that valve, and continues to pass through it, till the piston B reaches its frame. The piston B then descends again, and brings up another supply of water, which after having filled the space above the valve *a*, begins to flow from the spout as in common pumps.

The forcing Pump

The forcing pump is furnished with two valves, which are both stationary, or open and shut in the same situation. This pump is shewn at fig. 7, pl. II, where EF is the working barrel, and G the pipe which descends into the water. The first valve is placed at *r*, and the second either at *s*, as in the figure, or in some part of the tube AB. The working rod H, terminates in a solid plunger or piston, K, which fits the barrel so well, as to allow neither water nor air to escape above it from below. Suppose this piston to be immediately over the valve *r*; when it is drawn up, the valve *r* opens, and the water passes through it, as through the lower valve in an ordinary pump. But on the depression of the rod H, the water cannot pass through the piston, because it contains neither valve nor any other aperture, nor through the valve *r*, because it closes with the retrograde motion of the piston; the water therefore enters the tube AB, raises the valve *s*, and enters the reservoir TT. The piston is then at liberty to be driven down towards the valve *r*, and each repetition of its action forces a fresh quantity of water through the valve *s*. The reservoir contains a tube *b b*, firmly fixed in its upper part, and reaching almost to its bottom. The effect of the water, on first entering it, is to drive out of it a quantity of air; but when the water has risen above the lower orifice of the tube, no more air can be driven out, and therefore the remainer of it is condensed, in proportion to the quantity of water forced into the reservoir by the action of the piston. It is obvious, however, from the elastic property of air, that there will be a re-action of the quantity thus confined, according to the intensity of the condensation. This re-action or

endeavour to acquire its former bulk, causes it to press upon the surface of the water, which, having no egress elsewhere, passes out of the tube *b b*, in the form of a jet. And as, during the descent of the piston K, there is more water in the reservoir TT, than the air can drive out in that space of time, the jet from the tube *b*, continues with little intermission of force during the whole time that the pump is wrought.

The reservoir TT, is called an *air-vessel.* Although the machine to which a vessel of this kind is added, discharges the water in a continual stream, it does not necessarily follow that a greater quantity is discharged in a given time than by a simple spout: theory, indeed, dictates that the quantity will in each case be the same; experiment, however, has established, that a little more is delivered when the air-vessel is used, though the difference is very small.

By means of the forcing pump, wrought by an adequate power, water may be raised to any height, but the distance between the piston K, when highest, and the surface of the water to be drawn up, must not exceed 33 feet, because it is by the pressure of the outward air that the water is raised in the first instance; for great heights, therefore, it is the pipe AB which must be lengthened.

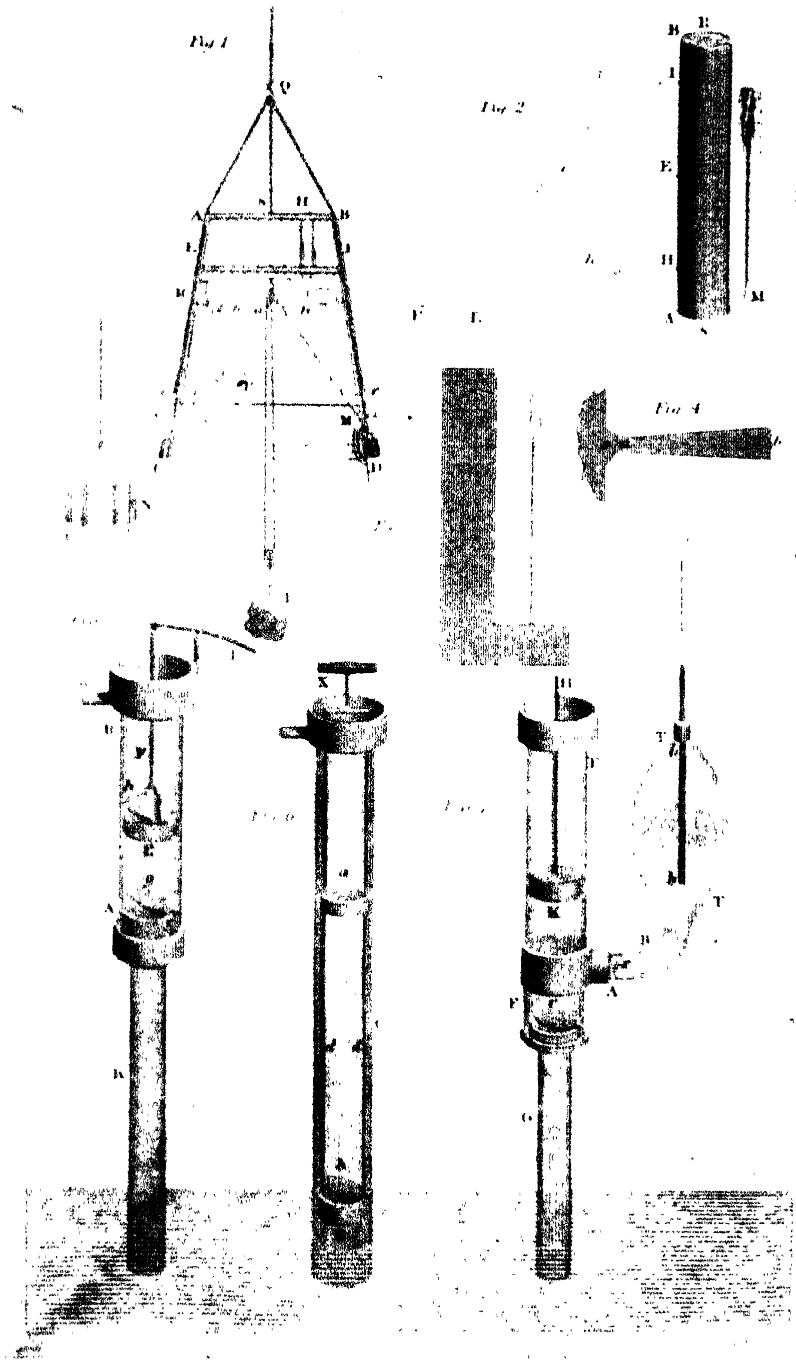
A forcing pump is the essential part of an engine for extinguishing fires. These engines have generally two forcing pumps, and the pipe from the air-vessel, except at the extremity, is made of leather, or some pliable material, that the jet may easily be directed to any given point: the pipe G is also in part made of leather, in order that a supply of water may be drawn conveniently up from any accidental source.

The pump was invented about one hundred and twenty years before the birth of Christ, by Ctesibius of Alexandria, the inventor of the organ, and the first example of it appears to have been a forcing pump.

Improved Pump.

Various attempts have been made to improve the construction of pumps, and several of them have not been unsuccessful; a contrivance for converting the common sucking pump into a lifting pump, we shall first notice. It is represented by fig. 1. pl. III, where AB is the working-barrel, which has a lateral pipe at C, connected with it: this lateral pipe turns up vertically, and is furnished with a valve at E. The barrel AB is closed by a strong plate at the top, containing a hole in its centre, furnished with a collar of leathers. This collar tightly

PLATE II



embraces a straight, true, and polished piston rod M, and the leather being soaked in tallow, or some other unguent, is perfectly air-tight. The piston S contains a valve, and there is another valve at T; both of them opening upwards. Now suppose the piston S to be at the bottom of the working-barrel, when it is drawn up, it tends to compress the air above it, and the valve in it remains shut by its own weight. But as the air will not suffer compression, while a possibility of escape remains, it passes along the tube LC, and makes its egress by lifting the valve K. The space between the piston S and the valve T, after a few strokes, becomes nearly a vacuum, the water then rises from the well into the working-barrel, after which the downward stroke of the rod M causes the water to lift the valve, and a column of it to get above the piston S. Upon drawing up the piston, therefore, this column is drawn up at the same time, and forced through the valve K. This is a very good form of a pump; for the piston-rod works with great steadiness, and as the piston may be brought very near the valve T, a great degree of rarefaction may be obtained. In this pump the valve T may either be in contact with the water, or elevated considerably above it, as in the figure: in the latter case it is the same as Buchanan's ship pump. By connecting an air-vessel with the rising pipe C, as in the forcing pump last described, this pump may be made to yield an unremitted supply of water.—Pumps for the supply of a house might be contrived on this principle, which in furnishing the ordinary supply of water, would work more easily than those commonly used, and in case of necessity they could instantly be converted into engines for extinguishing fire, or for supplying distant places with water. For common use, the spout of the pump should be opposite the horizontal part of the pipe C, and when the water was to be impelled to a distance, this spout should be bunged up. If a large cock were used as the spout, the closing of this cock would answer the same end.

De la Hire's Pump.

This is an ingenious though rather complex contrivance, for raising water both during the descent and ascent of the piston in the pump-barrel.

AA, fig. 2, pl. III, is a well, in which the lower ends of the pipes B and C are immersed. D is the working-barrel; into the lowermost end of it the top of the open pipe B is soldered: to the uppermost end of the barrel D the pipe CS is soldered, and opens into D. Each of these pipes B and CS has a valve on its top, and so have the crooked pipes E and F, the lower

ends of which open into the pump-barrel, and their upper ends into the box G. L is the piston rod, which moves up and down through a collar of leathers in the neck M. K is a solid piston, fastened to the rod L: the piston never goes higher than K, nor lower than D; so that the space between K and D is the length of the stroke.

As the piston rises from D to K, the atmosphere pressing on the surface of the water AA, in the well, forces the water up the pipe B, through the valve *b*, and fills the working-barrel with water up to the piston; during this time the valves *e* and S lie close and air-tight on the tops of the pipes E and CS. When the piston is at its greatest height, at K, it stops there for an instant, and in that instant the valve *b* falls, and stops the pipe B at the top. Then, as the piston descends, it cannot force the water between K and D back through the closed valve *b*, but forces the whole of that water up the pipe E, to the valve *e*, this valve immediately opens upward by the force of the water, which, after having filled the box G, rises into the pipe N, and runs off by the spout O.

During the descent of the piston K, the valve *f* falls down, and covers the top of the pipe F; and the pressure of the atmosphere on the water AA, of the well, forces the water up the pipe CS, and through the valve at the top of that pipe into the pump-barrel, where it fills all the space above the piston K.

When the piston is down to its lowest station at D, and stops there for an instant, the valve at S closes; and then as the piston is raised, it cannot force the water above it back through the valve S, but drives it up the pipe F, to the valve *f*, which opens upward by the force of the ascending water, and after filling the box G, the water is forced up from thence into the pipe N, and runs off by the spout at O. Thus as the piston descends, it forces the water below it up the pipe E; and as it ascends, it forces the water above it up the pipe F; the pressure of the atmosphere filling the pump-barrel below the piston, through the pipe B, while the plunger ascends, and filling the barrel with water above the piston through the pipe CS, as the plunger goes down. By this means, as much water is forced up the pipe N, to the spout O, by the descent of the piston as by its ascent; and, in each case, as much water is discharged at O, as fills that part of the pump-barrel in which the piston moves up and down.

On the top of the pipe O is an air-vessel P. When the water is forced up above the spout O, it compresses the air in the vessel P; which of course acts by its elasticity as in the air-vessel of the forcing pump already described.

Whatever may be the height of the spout O above the surface of the well, the top S, of the pipe CS, should only be 24 or 25 feet above the surface; for though the pressure of the atmosphere, in case the pipe were perfectly exhausted, would raise the water higher, yet as a perfect exhaustion can scarcely be attained, to make it longer would be running the risk of imperfect action.

It is not very material what the size of the pipe N may be, through which the water is forced into the spout; but much disadvantage may be incurred, by an injudicious proportion of the working-barrel; according to the height of the spout O, above the surface of the well, the diameter of the bore of the barrel should be as follows:

Height in feet to which the water is to be raised.	Bore of the barrel in inches.	Height in feet to which the water is to be raised.	Bore of the barrel in inches
10	6.9	55	2.9
15	5.6	60	2.8
20	4.9	65	2.7
25	4.4	70	2.6
30	4.0	75 and 80	2.5
35	3.7	85	2.4
40	3.5	90	2.3
45	3.3	95	2.2
50	3.1	100	2.1

The Screw of Archimedes.

This useful invention originated with the famous Archimedes of Syracuse. It is represented at fig. 3, plate III, and is formed by wrapping a tube round a cylinder, in the form of the thread of a screw. The cylinder is suspended upon pivots, and turned by means of a winch; its position is inclined to the horizon, with its lower end in the water to be raised. The tube or spiral is open at both ends, and when, by turning the winch, the lower orifice G strikes the water, the water gradually rises in the tube, till it is at last discharged at the upper orifice H. To explain the action of this machine, it may be necessary to observe, that while the lower orifice G is turned against the water, the water must be continually rising in it; and it is by its constantly endeavouring to remain on the under side of the tube, that it at last reaches the top. Thus suppose a quantity of water to lie on the under side at *f*, the spiral as it revolves brings the point *f* into the higher situation *k*, but the water which was in that part when it was at *f*, falls

back, because it cannot from its gravity ascend to *k;* but in doing this, it runs along an inclined plane, and gets part of a turn higher in the spiral, and the same process being continued through every instant of the working, the water flows out at H in a constant stream.

When the water is raised out of a river by means of this screw, if a wheel with float-boards be fixed on the lower axis G, the screw will be wrought by the stream itself.

A single spiral tube will raise but a small quantity of water; it is therefore common to wrap two or more tubes about the same cylinder; as the power required will be little greater, although each spiral will raise an equal quantity of water.

The screw of Archimedes should always be so placed, as to fill exactly one half of a convolution at each turn; for want of attention to this circumstance, it has been considered less effective than it really is; for when the orifice is constantly immersed, the effect is very much diminished. The machine is generally placed in an angle of between 45 and 60 degrees with the horizon.

A machine on this principle may be formed by means of spiral projections within a hollow cylinder, in which case it will resemble the box or socket of a screw; in this machine, which is called a *water-screw*, about one-third of the water generally runs back; yet it is equal to the screw of Archimedes, if the height of the water is so variable, that the latter cannot be placed in such a manner as to fill one-half of a convolution in each turn. It is placed only at an angle of 30 degrees.

Machines of this description are not calculated to raise water with advantage to great heights; for if made of the requisite strength to prevent their bending, they would be extremely heavy.

If we wind a pipe round a cylinder, of which the axis is horizontal, and connect one end with a vertical tube, while the other, which must be outermost, is at liberty to turn round and receive water and air in each revolution, the machine is called a *spiral pump*. It was invented in 1746, by Andrew Wirz, a pewterer in Zurich. At Archangelsky, near Moscow, a pump of this kind was erected in 1784, which raised a hogshead of water in a minute, to the height of 74 feet, and through a pipe 760 feet in length. The vertical pipe should be nearly of the same dimensions as the spiral pipe.

The Rope Pump.

If a pulley, set in motion by a large wheel, is fixed in a suitable frame over the mouth of a well, while another pulley is situated in a similar position in the water of the well, and an endless rope passes over both pulleys; on revolving the large wheel, every part of the rope will successively dip into the well, and after attaining the top of the upper pulley, will, in descending, throw off, by its centrifugal force, a portion of the water it has imbibed, the quantity of which, when the rotation is quick, will be very considerable.

A machine of this kind is represented at fig. 4. plate III; A is the small wheel or pulley over the mouth of the well; B the small wheel immersed in the water of the well; both these wheels are fixed upon iron axles, and turn with freedom in their respective frames. H is a hair rope passing over both pulleys, its two ends being neatly spliced, so as to constitute it an endless rope. EFGH is the section of a box containing the pulley A. From the bottom of this box stand up two tubes, *ef*, through which the two sides of the endless rope pass, and they are wide enough to admit of this without causing the rope to rub against them. On the same axle with the pulley A, but at the outside or back of the box, is another pulley, not seen in this figure. From this second pulley to the fly-wheel C, passes a band, so that on turning the winch D, a rapid motion is immediately communicated to it, consequently to the pulley A, and lastly by means of the rope H to the pulley B. The rope H, therefore, immediately ascends in one tube, and descends in the other. In ascending it carries up a quantity of water, a considerable proportion of which is thrown off in the box EFGH, before it enters the tube through which it descends. The water thus collected, runs in a continued stream out of the box, by the pipe L, as long as the fly-wheel is kept in motion. The use of the tube *ef* is merely to prevent the water, thrown off and collected in the box, from running out except at the spout L.

In this machine, the motion of the rope should be very rapid, or it will not produce its best effect. A rope of horse-hair, about half an inch in diameter, brought up, and discharged from the spout, six gallons of water per minute. The velocity of the rope was about 16 feet per second, and the depth of the well 95 feet. A machine of the same kind, on the round tower of Windsor castle, draws the water from the depth of 178 feet.

It is not essential to the action of the machine, whether the rope be made of hair or hemp, but hair is the more durable material: the chief disadvantage of the pump is the great liability of the rope to decay, from being constantly wet.

Hydraulic Bellows.

In situations where a fall of water can be conveniently obtained, a blowing machine may be constructed with great facility and at a trifling expense. Professor Venturi has given the following account of the application of a stream of water to this purpose.

"Let BCDE, fig. 5, pl. III, represent a pipe, through which the water of a canal AB, falls into the lower receiver MN. The sides of the tube have openings all round, through which the air freely enters to supply what the water carries down in its fall. This mixture of water and air proceeds to strike a mass of stone Q; whence rebounding through the whole width of the receiver MN, the water separates from the air, and falls to the bottom at XZ, whence it is discharged into the lower channel or drain, by one or more openings TV. The air being less heavy than the water, occupies the upper part of the receiver, whence, being urged through the upper pipe O, it is conveyed to the forge.

"I formed one of these artificial blowing machines of a small size. The pipe BD was two inches in diameter, and four feet in height. When the water accurately filled the section BC, and all the lateral openings of the pipe BDEC were closed, the pipe O no longer afforded any wind. It is therefore evident, that in the open pipes, the whole of the wind comes from the atmosphere, and no portion is afforded by the decomposition of water. Water cannot be decomposed and transformed into gas, by the simple agitation and mechanical percussion of its parts. The opinions of Fabri and Dietrich have no foundation in nature, and are contrary to experiment. It remains, therefore, to determine the circumstances proper to drive into the receiver MN, the greatest quantity of air, and to measure that quantity. The circumstances which favour the most abundant production of wind, are the following:

"1. In order to obtain the greatest effect from the acceleration of gravity, it is necessary that the water should begin to fall at BC, with the least possible velocity; and that the height of the water FB should be no more than is necessary to fill the section B. I suppose the vertical velocity of this section to be produced by a height or head equal to BC.

"2. We do not yet know by direct experiment, the distance to which the lateral communication of motion between water and air can extend itself; but we may admit, with confidence, that it can take place in a section double that of the original section with which the water enters the pipe. Let us suppose the section of the pipe BDEC, to be double the section of the water at BC; and in order that the stream of fluid may extend and divide itself through the whole double section of the pipe, some bars, or a grate, are placed in BC, to distribute and scatter the water through the whole internal cavity of the pipe.

"3. Since the air is required to move in the pipe O with a certain velocity, it must be compressed in the receiver. This compression will be proportioned to the sum of the accelerations, which shall have been destroyed in the inferior part KD of the pipe. Taking KD equal to one foot and a half, we shall have a pressure sufficient to give the requisite velocity in the pipe O. The sides of the portion KD, as well as those of the receiver MN, must be exactly closed in every part.

"4. The lateral openings in the remaining part of the pipe BK, may be so disposed and multiplied, particularly at the upper part, that the air may have free access within the tube. I will suppose them to be such, that one-tenth part of a foot high of water, might be sufficient to give the necessary velocity to the air, at its introduction through the apertures.

"If the pipe O do not discharge the whole quantity of air afforded by the fall, the water will descend at XZ; the point K will rise in the pipe, the afflux of air will diminish, and part of the wind will issue out of the lower lateral apertures of the pipe BK."

The Siphon.

A uniform tube, bent in the form shewn at *a b c*, fig. 6, pl. III, is called a *siphon*, which instrument is in common use for decanting fluids. Let RS be a vessel of water, which we wish to draw off; the siphon must be first filled with water, then applying the finger to each orifice, the shorter leg is placed in the vessel, and the water immediately runs out at the longer leg *c*, until the water in the vessel is as low as the orifice of the shorter leg *a*. The siphon will not act in vacuo; it is to the pressure of the atmosphere we are indebted for its effects. When the instrument, filled with water, is turned down as represented in the figure, and left to itself, the column of fluid contained in the leg *b c*, is longer, and consequently heavier

than that contained in the leg *b a*; and as the pressure of the atmosphere at each orifice is the same, the longer column of water is not so much resisted as the other; it therefore flows out at the orifice *c*, and the pressure of the atmosphere on the water in the vessel RS, presses up the water at *a*, with the same rapidity that it escapes at *c*.

In the siphon, it is observed above, that the leg *b c*, which is out of the fluid, should be the longest, and accordingly, siphons are always constructed with one leg longer than the other. It does not, however, necessarily follow, that water will in no case flow out of a siphon, of which the legs are equal; and it may not be improper to explain the cause: whatever is the real length of the leg *b a*, the virtual or acting length when in use, only extends from *b* to the surface of the fluid; because the water it contains, reckoning downwards from the surface of the water in the reservoir, is balanced by the equal perpendicular height of the column of water around it, and has no concern with the action of the instrument. Hence the making of the leg *b a*, much longer than what is requisite to reach to the surface of the fluid, is only a matter of convenience, to prevent the necessity of lowering the siphon every instant, which in most cases would be impossible, on account of the edge of the reservoir; and yet would be indispensable, unless the fluid always remained at the same level, which case rarely occurs.

For the operation of filling the siphon, and then inverting it in the fluid to be drawn off, is often substituted that of drawing out the air with the mouth by sucking at the orifice *c*, till the fluid comes over; but as either operation is ineligible with all fluids or large siphons, other simple contrivances have been adopted to effect the same end. Thus a stop-cock may be applied to each end of the siphon, which may then be filled with fluid from an aperture at the top; taking care to close this aperture before the others are opened. Or, for small siphons, when the position required is the only objection to extracting the air from the orifice *c*, fig. 6, a stop-cock and the tube in the position shewn by fig. 7, may be used, and the mouth applied at F.

The legs of the siphon, fig. 6, are inclined from each other, while those of the siphon, fig. 7, are parallel; this difference has nothing for its object but to shew two different forms of the same instrument, and which are adopted as convenience dictates. Thus the siphon, fig. 6, may be used to discharge liquor by inserting it in the bung-hole of a barrel, to which purpose the other would be inapplicable. But whatever be the form of a siphon, the length of its legs, when in use, must be

measured in a direction perpendicular to the horizon; hence the same siphon, inclined in different directions, will, as to its operation, be of different lengths.

The column of water in the leg *b a*, of a siphon, being supported by the pressure of the atmosphere, it follows, that when that leg would require a longer column than is equivalent to the atmospheric pressure, the water will not be raised: water will not therefore rise in a siphon, any more than in a pump, beyond the height of 33 feet. If mercury were the fluid to be raised by a siphon, the length of the column in the leg *b a*, must not exceed that of the barometer at the time; that is, about 29 or 30 inches; which is only about a fourteenth part of the height to which water is raised, because the density of mercury is nearly fourteen times greater than that of water.

Though water may be raised in the siphon to any height not exceeding 33 feet, yet it must be noted that the orifice of delivery is always below the head of the fluid in the reservoir; it is not therefore raised above its level to any useful purpose, independent of that which consists merely in drawing off a fluid. But though, while the discharge by the common siphon continues, no water can be taken out of the stream above the lowest part of the tube, yet if the two apertures at the end be closed, a quantity of water may be let out of the highest part, and its place supplied by a like quantity which is of no other use. The apertures might be easily contrived so as to close or open simultaneously, and thus, at an elevation of 30 feet above the reservoir, a supply of clean water might be obtained in lieu of dirty; but where the waste of water is an object, the contrivance is of little value. A simple method of taking water out of a siphon, at any height within the limits of the instrument, would certainly be a considerable acquisition in the arts; and the best experiments to attain this object, appear to have been made by William Close, of Dalton, (see Nicholson's Journal, 4to. vol. 4.) He supplied, in the following manner, the place of water drawn from a siphon. Into any part except the top side of a vertical siphon SY, fig. 8, insert two small pipes, and let their apertures in the inside of the tube be divided by a projecting piece about a quarter of an inch thick; wherever the pipes are inserted, the piece must be placed in such a position that the current will strike against one of its flat sides. The pipe which opens on that side of the obstacle or dam struck by the stream, may be called the *water-pipe*, and that on the other side the *air-pipe*. Insert their other ends into a vessel *a w*. The air-pipe opposite to *a*, must rise to near the top of this vessel, but the water-pipe, *w*, need not rise above the place of its insertion. A cock, perfectly air-tight,

must be fixed in each pipe between the vessel and siphon: the vessel *a w*, must have a tube *t* in its lower part, for letting out water; and this tube must have a cock fixed in it, or a valve covered with leather to close its lower end. To hasten the delivery of the water in this vessel, the external air may be admitted, in such a manner as may be most convenient.

The communication between the vessel and siphon being intercepted by turning the cocks in the pipes *a w*, and the branches of the siphon closed at their lower ends, the tube may be filled with water through an aperture at the top. After this aperture is closed, and a stream of water let into the cistern C, for supplying the siphon, the ends of the branches may be opened, and a continued stream will flow through the tube.

When it is required to fill the vessel *a w* with water, exclude the external air, and open the pipes between it and the siphon. The vessel will soon be filled, and the water may be let out by opening the tube *t*, after the small pipes *a w* are again closed by turning their cocks.

The water may be let out of the vessel without attendance, by a quantity of water passing through four vessels placed in the following order one below another, and each provided with a siphon:

1. The highest, an immoveable vessel filled in a given time. 2. A descending vessel, suspended from a lever or a wheel, which turns the cocks in the tubes opposite *a w* in its axis. This vessel must have a tube open at both ends, fixed in the middle of its bottom. 3. A descending vessel, to open the valve for letting water out of the vessel *a w*. It must be suspended upon the valve by a cord or wire passing through the tube, in the middle of the second vessel. 4. The lowest, a vessel of the same width with the second. The brim of it must be connected to the outside circumference of the bottom of the second, by wires or chains.

In this arrangement, the first vessel will empty itself into the second, which will close the cocks in the pipes opposite *a* and *w*, before air is admitted into the vessel *a w*. The third will be filled from the second, and the water in the vessel *a w* will be let out again; the third will deliver its contents into the fourth or lowest, which will keep the cocks in the small pipes opposite *a* and *w* close, until after the third vessel is empty, has risen up, and the external air can no longer enter the vessel *a w*. The fourth being then emptied by its siphon SY, will open.

The diameter of the second vessel should be something less than either that above or below it. The fourth should be filled

before the second is empty: the third will descend last, and rise first: the second and fourth will rise together, immediately after the third. If the second and fourth were to rise before the third, the siphon would directly receive a quantity of external air, and its operations would cease. It will therefore require much caution to manage the cocks and valves, if another vessel similar to *a w* is to be filled while this last is emptied, and emptied while it is filled.

The vessel *a w* should not be large; and, in order to overcome the buoyancy of the extracted air, it is advisable to make the length of the descending branch of the siphon exceed the length of the ascending one as much as circumstances will admit, and to let the lowest part of it be made of a conical divergent form, as from *a* to *b*, fig. 4, pl. II. The velocity of the stream will be thus increased, the vessel *a w* will be sooner filled with water; and the depression of the two columns will be less liable to happen from very slight imperfections of workmanship. In the octavo series, No. 45, of Nicholson's Journal, this subject is pursued, and the description and effects of an apparatus for raising water by means of air condensed in its descent through a siphon, are given.

In estimating the discharge by a siphon, the head of water must be reckoned equal to the difference between the levels of the surface of the water and of the lower orifice. The reason of this will be obvious, when, as already explained, it is recollected that the length of the shorter leg is only measured to the surface of the water, however far it may reach below, and that, as the action of the instrument is dependent on the discharging leg being the longer of the two, the greater the difference in favour of this leg, the greater will be the force employed in promoting the discharge.

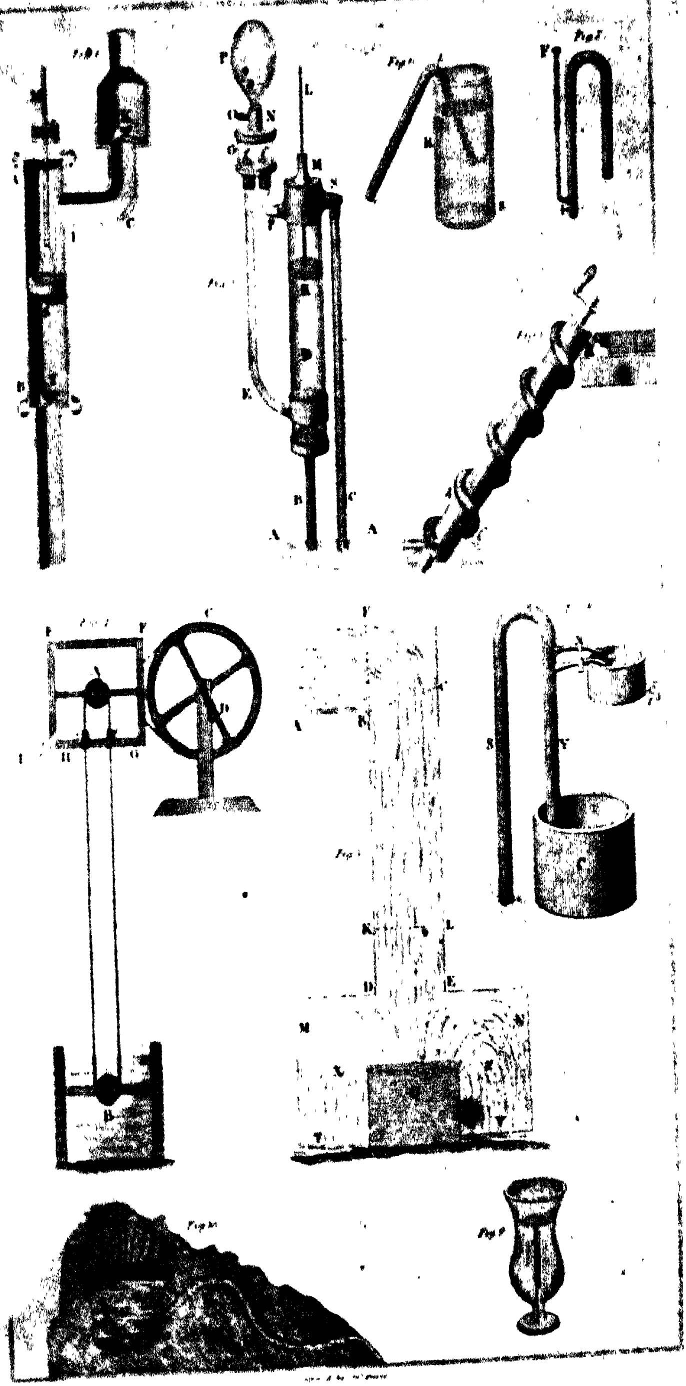
To serve the purpose of amusement, a siphon is contrived to draw off the liquor from a cup which a person holds up to his mouth. This device may be understood from fig. 9, pl. III. The siphon is comprised in the smallest compass possible; its branches are therefore quite close; but it is necessary that, in proportion to the size of the cup, it should have a bore sufficiently wide to draw off the contents with some degree of rapidity. The longer leg of the siphon passes through the bottom of the cup. When any fluid is poured into this cup, it will not run out, till its height exceeds the level of the siphon's curvature; it may therefore be filled so high that the fluid will run out as soon as the glass is inclined in the position for drinking, and not while it is held upright; if then it be so filled, and presented to a person unapprised of the trick; the liquor will, unexpectedly to him, begin to flow out, and

the discharge will continue till the whole of the fluid in the cup, except the small quantity contained between the orifice of the shorter leg of the siphon and the bottom, is passed off. A vessel thus employed, is called *Tantalus's cup*, from Tantalus, a person who, in fabulous history, is declared to be punished by the perpetual proximity of blessings he can never reach.

The intermittent or reciprocating wells which sometimes occur in nature, and are to the vulgar so much the objects of wonder, are well accounted for on the principle of the siphon. When the water, percolating through the crevices of a mountain, falls into a cavity, as represented at G, fig. 10, the outlet to which is only by a narrow channel or vein in the form shewn at H, it cannot immediately make its egress at *b*; it therefore collects in the basin G, till its level there is as high as that of the top of the vein H; as soon as this takes place, the vein H, which acts as a siphon, draws off the water till the level of the quantity left in the reservoir G, is below the commencement of the vein at *a*.

The Steam Engine.

The first person who entertained the idea of employing steam as a motive-force, is not certainly known; but the earliest application of steam to this object, is not carried further back than the year 1629, when an Italian, called Brancas, published an account of an invention of his, in which steam ejected from a large æolipile was the force that wrought a stamping engine. Thirty-four years afterwards, in 1663, the Marquis of Worcester, a nobleman of great ingenuity, published a little work called "A Century of Inventions," in which one hundred contrivances of his own are enumerated: the account he furnishes of each is short, and often very obscure; with the latter fault is particularly chargeable, the description he furnishes of an engine for raising water by the force of steam. At this day, we have no means of certainly knowing whether the discovery of Brancas was known to the Marquis or not; but it is not suspected that he was acquainted with it, and therefore the English are inclined to consider the original idea of the steam engine as having arisen in their own country: the French, on the contrary, claim it for themselves, and bring forward the name of Papin; but Papin's application of steam as a motive-force, was not published till 1690, which was 27 years after the Marquis of Worcester's publication. But let it even be supposed that for Brancas, the Marquis, and Papin, the claim to independent and original invention could be substantiated;



yet the Italians and French have no claim to notice afterwards, for following up the ideas of their countrymen; it is solely to the English that the world is indebted for rendering the steam-engine what it now is, the noblest machine ever invented by man;—the pride of the mechanist—the admiration of the philosopher.—Animals require long and frequent periods of relaxation from fatigue, and any great accumulation of their power is not obtained without great expense and inconvenience; the wind is mutable to a proverb; and water, the constancy of which is in few places equal to the wants of the mechanist, cannot in general be obtained on the spot where other circumstances require machinery to be erected. To relieve us from all these difficulties, the last century has given us the steam-engine for a resource; the power of this assistant may be accumulated indefinitely; it requires but little room; it may be erected in all places; and its mighty services are always at our command; whether in winter or in summer, by day or by night, it knows of no intermission but what our wishes dictate.

In this place it may not be improper to say a few words on the properties of the agent from which this engine derives its distinguishing epithet. Water is converted into steam by its combination with caloric. Various estimates have been made of the degree in which steam expands, when compared with the bulk of water from which it was produced; but they differ widely from each other: Beighton deduced from an experiment he made for the purpose, that the expansibility of steam to water was as 2886 to 1; Desaguliers stated it at 14,000 to 1; and the editors of the Encyclopedia Britannica, on the authority of experiment, at 10,000 to 1; but in the supplement to the last-named work, the expansibility is stated to be as 1800 to 1. Parke, in his Chemical Catechism, only considers it as 800 to 1. These conclusions are too discordant to be reconciled; yet nothing absolutely decisive can be opposed to them. The density of water (see page 2 of this volume) has been established by very exact experiments, to be to air as 832 to 1; yet in the very dense state in which steam issues from a vessel nearly close, the pipe of a kettle, for example, it rises with great rapidity in air; it is therefore much lighter than air; and from this evidence we may conclude that Parke's statement is too low. Again, as clouds, which are but aggregated vapours, (though philosophers have not been able to assign the precise cause of aggregation,) are observed at the height of three or four miles, where the density of the air is not half of what it is at the earth, it may be supposed that the rarity of steam is at least twice as great as that of common air. It is true, that moisture is contained in the atmosphere at greater

heights than three or four miles, but it is probably then in a state not simply of mechanical suspension, but of chemical combination. As to the space which steam would fill in a complete vacuum, it has no relation to the subject; if it had, it might be said without fear of error, that a drop of water converted into steam, would, like a grain of air, fill the universe: the tendency of steam to burst a vessel, is always less than its absolute force, by the amount of the atmospheric pressure. If then we take the density of steam, under the ordinary pressure of the atmosphere, to be to the density of water as 1800 to 1, we shall not probably be very far wrong. The boiling point of water, that is, the heat at which it is converted into steam, is 212 degrees of Fahrenheit's scale; and when water is heated to this degree, the vapour from it resists compression, or makes an effort to expand, with a force exceeding that of gunpowder, and this effort is continued, though with diminished intensity as the bulk of the steam increases, till it has acquired 1800 times the bulk of the water that produced it; when it becomes entirely inert, and has no more tendency to burst a vessel containing it, than if that vessel were filled with as much common air; for the pressure of the air, and the tendency of the steam to a further expansion, are an exact balance to each other. From the great power with which steam endeavours to expand, and the instantaneous manner in which it exerts its energy, it is obvious, that if it could be directed at regular intervals against any body capable of motion, it might be rendered a powerful first mover. We shall therefore postpone any further remarks on steam, until we have given a general view of the manner in which the knowledge of the properties already developed have been applied.

The first person who attempted to realize the invention of employing steam, as suggested by the Marquis of Worcester, was Captain Savary, who was so far successful, that he obtained a patent for his invention, towards the close of the seventeenth century, and several of his engines were actually constructed. In 1696, he gave an account of them, in a work which he published, entitled the "Miner's Friend." About this period, apprehensions were entertained, that mines, otherwise of immense value, must be abandoned, unless more powerful and economical means were adopted of drawing the water from them; hence the most valuable purpose, which any new motive-force could be employed to effect, appeared to be that of drawing up water, and this object Captain Savary effected by steam in the following manner: a pipe descended into the water of the mine, and terminated at the top in a large

receiver, which may be compared to a square chest; the upper orifice of the pipe was covered by a valve opening upwards. Into the receiver opened a pipe communicating with the upper part of a close boiler; the boiler was about half filled with water, and set in a furnace, as boilers for supplying steam are at present, so that the requisite heat of the water could be constantly kept up. The pipe that connected the boiler and the receiver contained a cock, by which the communication between these vessels could at any time be suspended or opened. At the commencement of the working, a quantity of steam was let into the receiver, which it filled, driving out the air it contained, through a valve properly situated for that purpose. The steam-cock was then closed, in consequence of which, as the receiver cooled, the steam which had entered it, condensed into water, and the space it occupied became nearly a vacuum. By this means, the pressure of the atmosphere was removed from that part of the water in the mine which entered the pipe rising from it to the receiver, and therefore, as in the suction-pipe of a common pump, the pressure on the rest of the surface forced the water to rise and fill the receiver. The equilibrium being thus restored, the valve of the pipe from the well closed by its own weight. The steam-cock was now opened, and the effect was, to drive the water out of the receiver through the valve at which it had previously driven out the air; this valve was in a pipe which rose perpendicularly above the receiver, but commenced at the bottom of it. Thus the receiver was again left filled only with steam, and a quantity of water, equal to its capacity, was discharged from the mine. In continuing the operation, a cock was opened which let into the receiver a quantity of water in the form of a shower; this produced a speedy condensation of the steam, the water rose again, and was again driven out as before.

Such was the first attempt to form a powerful engine by the use of steam. It is unnecessary to enter more minutely upon the details of an engine not now in use: its construction was extremely simple, but it had several important defects. As the water was raised into the receiver by the pressure of the atmosphere, the distance between the receiver, and the surface of the water in the well, was limited to about thirty feet, and the discharging pipe could not be continued to any great length above the receiver, without requiring a proportionate density of steam to overcome the pressure of the column of water which thus burdened or pressed back upon the receiver: thus when the column of water rose 33 feet above the receiver, the steam required was equal to the resistance of two atmospheres. Indeed, the highly elastic force

of the steam which the engine required, frequently burst the vessels. Another great defect, also, was the rapid destruction of steam by its coming into contact with the cold water in the receiver, the contents of which were slow in yielding to its pressure; and with the rapid destruction of steam was necessarily connected a heavy demand for fuel.

About the beginning of the last century, that is, a few years after the publication of the "Miner's Friend," Newcomen, an ironmonger, and Cawley, a glazier, of Dartmouth, in Devonshire, conceived the idea of improving Savary's engine; but their exertions terminated in the adoption of a new principle, of memorable consequence in the history of this invention. They were satisfied, notwithstanding, to divide with Savary the benefits likely to accrue from their improvements, and in 1705, a patent was obtained in which all three were joined; it was not, however, till 1712, that they had made any very material progress in overcoming the various difficulties which impeded their progress. Savary's engine, we have seen, raised water by the force of steam acting directly upon the water; Newcomen's engine raised it by the pressure of the atmosphere, which was rendered effective in a very powerful degree: a boiler for producing steam was used as in Savary's engine; there was also a steam-pipe which opened into the bottom of a hollow cylinder; the entrance of the steam into the cylinder could at any time be cut off, by sliding a flat plate over that end of it which entered the boiler, and this motion was easily effected by an external handle connected with the plate. To the cylinder, which was open at the top, was adapted a solid piston, which slid up and down in it, and was rendered air-tight by a stuffing of soft materials on its circumference. Suppose, in one of these engines, the piston to be at the top of the cylinder, a quantity of steam from the boiler is let in, and fills the space below it; the air which the cylinder contained being driven out by the superior force of the steam, through a valve made for that purpose. As soon as the cylinder is filled with steam alone, a jet of water from an elevated reservoir, enters at the bottom of the cylinder, and the steam is immediately condensed. As the pressure of the atmosphere on the upper side of the piston is equal to fifteen pounds upon every square inch, the counterpoise to this pressure afforded by the steam, is no sooner removed by the condensation, than the piston rapidly falls to the bottom of the cylinder; for the water injected, and that produced by the condensation, are not only of little bulk compared with the whole capacity of the cylinder, but are carried off by a pipe from the bottom of it. The steam-pipe being now re-opened, the piston

again rises, because the elasticity of the steam which impels it, exceeds the atmospheric pressure; but when the steam is condensed again, the piston falls a second time as rapidly as before. Having thus obtained a reciprocating motion, Newcomen applied it to the working of a forcing-pump, by the intervention of a great beam, suspended on gudgeons at the middle, and swinging like the beam of a balance, and this part of his engine is in use to this time. A rod from the centre of the piston was attached to one end of this beam, by a short piece of chain; and to the other end, by a similar piece of chain, was connected the rod of the forcing-pump; every time, therefore, that the piston sunk in the cylinder, the rod of the pump which extracted the water from the mine, was drawn up; and as this end was purposely made heavier than the piston end, the piston rose when the steam was let under it, although this steam might have so little elasticity, as only to be just a counterpoise to the weight of the atmosphere.

Whatever objections might be urged against Newcomen's engine, if critically examined at this day, still it was a great effort of mechanical genius, and he must ever be considered as substantially the inventor of the steam-engine, and as having presented to the world a machine of which the power is unlimited; for it is obvious, that by enlarging the size of the cylinder, the atmospheric pressure upon it may be made to exceed, in any degree required, the weight of the column of water to be raised. The alterations which have been made in the construction of steam-engines, since the time of Newcomen, although they have required much ingenuity, and have made prodigious accessions to the convenience of the engine, can only be considered in the light of improvements. Two very material improvements, however, introduced by Watt, we must particularly specify, 1. that of making the steam itself depress the piston instead of the pressure of the atmosphere: 2. That of condensing the steam in a separate vessel.* Further we can do little more than observe, that the steam-engine, as now constructed, is not the work of any single individual, but the aggregated product of the exertions of the most eminent engineers who have flourished during the last century. It would require a volume to discuss the claims of individuals, and assign to each his due meed of praise. We shall therefore proceed to the more useful task

* A claim to the first thought of this improvement, is supported on behalf of Gainsborough, a brother of the painter of that name, and it has been asserted that it was surreptitiously revealed to Watt. See Gregory's Mechanics, vol. 2.

of concisely describing a modern steam-engine, observing only, that the judicious arrangements in its construction, are at present ably seconded by the highly advanced state of the manual arts; for the mechanical excellence of the workmanship of the parts, is in such an engine an object of primary importance. Newcomen and Cawley had not this advantage; turning, boring, and other methods of producing regular forms in iron and metals generally, were then in a very low state; and their power of invention, as well as that of the performance of their engine, was thus considerably narrowed. It was not to be expected that they could carry to perfection at once, the various processes of workmanship, upon which much of their success depended. At the same time, there can be no doubt, that the necessity for improved methods of executing the workmanship of the steam-engine, has been one of the principal stimuli which have led to the most successful changes, and which have benefited every other department requiring manual skill, or substances formed with the strictest mechanical accuracy.

Manufactories of steam-engines are now very numerous, particularly in those districts where machinery is much required, and almost every where they are constructed with some differences. We have been favoured with the annexed representation, (see plate, Steam-Engine) from a House, in our application to which we had been directed solely by the celebrity they have derived from an active attention to whatever could contribute to the value of their engines.

A, the boiler, nearly three-quarters full of water; the bottom is considerably, and the sides a little concave, that it may receive more fully the force of the flame circulating round it. Boilers are usually of an oblong form, and are furnished with a part that takes off, in order that a person may get in to clean them when needful; they have also a valve, called the safety-valve, opening upwards, which is loaded so that the steam escapes when it is stronger than the engine requires, and, if retained, would hazard the bursting of the boiler. It is not uncommon to have two boilers, one of which is a reserve, that the engine may not be stopped, when the other requires repair.

B, is an apparatus for regulating the fire, and giving action to a bell, which regulates the quantity of coals and time of firing.

C, the steam-pipe from the boiler A to the valve I.

D, the steam-cylinder, generally called only "the cylinder;" it is connected at the top and bottom with the valve I.

E, the piston, which, by its connecting rod *e*, gives motion to the beam F, the other end of which, by another connecting rod, gives motion to the heavy fly-wheel G, by means of a crank. Thus, after the engine has begun to work, its power is accumulated in the fly-wheel, and may be disposed of at the pleasure of the mechanist.

H, an eccentric circle* on the axle of the fly-wheel G; it gives motion by its levers, in a manner easily understood by inspection, to the valve I.

I, a coffer-slide valve, which requires no packing to make it steam-tight, as there is always a vacuum under it: it answers the purpose of the four valves used in double-power engines, and from the simplicity of its construction, when well made at first, is not liable to get out of order.

K, the steam-admission valve and lever, connected with a governor, which regulates the speed of the engine.

L, the cylinder of the discharging pump, for extracting the water and uncondensed vapour from the condenser M.

N, a small cistern, filled with water. Into this cistern enters a pipe from the condenser M, the top of which pipe is covered by a valve, which is called the blow-valve, or sometimes the snifting-valve. Through this valve, the air contained in the cylinder D, and passages from it, is discharged, previously to the engine being set in motion.

O, the eduction-pipe, which couducts the steam from the valve I to the condenser M.

P, the pump which supplies with water the cistern SS, in which the condenser and discharging pump stand.

QQ, iron columns, of which the engine has four, although only two are shewn; they stand upon one entire plate seen edgeway, on which the principal parts of the engine are fixed; by this means the beam and its accompaniments are supported without being connected with any part of the building, except the recess below the floor on which they stand.

RR, the recess below the floor, for containing the cistern of the discharging-pump, condenser, &c. This arrangement enables those engines to be fixed up and tried at the manufactory before they are sent off, which renders the refixing easy and certain. Engines are made according to this plan, from the power of one to twelve horses.

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* Mechanics distinguish by the appellation of "eccentric circle," a wheel, the axle of which is purposely made to pass, not through its real centre, but on one side of it.

Before the engine is set to work, the cylinder D, the condenser M, and the passages between them, are filled with common air, which it is necessary to extract. To effect this, by opening the valves, a communication is made between the steam-pipe C, the space below the piston in the cylinder D, the eduction-pipe O, and the condenser M. The steam will not at first enter the cylinder D, or will only enter it a little way, because it is resisted by the air; but the air in the eduction-pipe O, and the condenser M, it forcibly drives before it, and this part of the air makes its exit through the valve and water in the cistern N. The steam-admission valve is now closed, and the steam already admitted is converted into water, partly by the coldness of the condenser M, but principally by a jet of cold water which enters it through a cock opening into it from the well SS, in which the condenser is immersed. When this steam is condensed, all the space it occupied would be a vacuum, did not the air in the cylinder D expand, and fill all the space that the original quantity of it filled; but by the repetition of the means for extracting a part of the air, the remainder is blown out, and the cylinder becomes filled with steam alone. Suppose then the cylinder beneath the piston to be filled with steam, and the further admission of steam to that part of it be cut off, while the communication between it and the condenser remains open, it is obvious that there will soon be a vacuum in the cylinder, because as fast as the steam reaches the condenser, it is converted into water by the coldness of that vessel and the jet playing within it. At this moment, therefore, the steam is admitted above the piston, which it immediately presses down. As soon as the piston reaches to the bottom of the cylinder, the steam is admitted to the under side of it, and as the communication from the upper side of the piston to the condenser is opened, while the further admission of steam to that side during the upper stroke, is prevented, the steam which had pressed the piston down passes into the condenser, and is converted into water.

The motion of the piston E, by this alternate admission and extraction of the steam on each side of it, is thus necessarily continued, and the distance of its upward and downward range is called the length of its stroke. It communicates its reciprocating motion, by the connecting rod *e*, to the great beam F, and thence, by another connecting-rod and a crank, to the fly-wheel G.

To explain the rapid accumulation of power with an increase of the size of the engine, it must be observed, that the force of the steam generally used, is somewhat greater than the

pressure of the atmosphere; but supposing it to be no greater, as the atmospheric pressure is fifteen pounds on each square inch, a piston 16 inches in diameter, containing 201 square inches of surface, will alternately be raised and depressed by a force equivalent to a weight of 3015 pounds. Here no allowance is made for friction, but after the requisite deduction on this account, which may be reckoned at one third, the disposable part of the engine, derived from each stroke, will still be very great.

The condenser M, and the discharging-pump L, communicate by means of a horizontal pipe containing a valve *y* opening towards the pump; the piston, *l*, of this pump, also contains two valves, and the cistern T, at the top of the pump-cylinder, contains other two valves, which, like those of the piston *l*, open upwards. When the piston E of the cylinder is depressed, the piston *l*, of the discharging-pump, it will be obvious to inspection, is depressed likewise, and its valves open, while the valve *y* closes; hence the water from the condensed steam, as well as the injection-water, and any permanently elastic vapour or gas, which may be present, having passed through the valve *y*, passes through the piston *l*; and when that piston is drawn up, its valves close and prevent their return, as in ordinary pump-work. The water and gas that have thus got above the piston, as the latter rises, open the valves at the bottom of the cistern T, in which the water remains till it is full, but the gas passes into the atmosphere. As the water in the cistern T is in a very hot state, it is sometimes, for the purpose of economizing fuel, pumped up and returned to the boiler, the pump-rod being attached to the great beam. The utility of the discharging-pump L, will now be appreciated, and it must be perceived how much more materially it contributes to the perfection of the vacuum in the cylinder D, than if the water from the condenser merely ran off by a pipe.

The steam constantly rushing into the condenser M, has a perpetual tendency to heat that vessel, as well as the water of the cistern SS, in which it stands: the whole of the steam, if this were unchecked, would not be condensed, or the condensation would not be sufficiently rapid, because the injection-water itself flows out of this cistern. A part of the water is therefore allowed to flow from this cistern by a waste pipe, and an equal quantity of cold is constantly supplied by the pump P.

In Newcomen's engine, which, as it acted by the pressure of the atmosphere, is often called an atmospherical engine the cylinder was open at the top, and therefore, during the

descent of the piston, the air exerted a great power in cooling it; but in the modern engines, where steam is the active power both in raising and depressing the piston, the top of the cylinder is closed with an iron lid, and not an atom of steam can escape, except at the proper time, into the condenser. In order that the connecting rod *e*, may work freely, and yet possess this desirable property of being steam-tight, it passes through what is called a *stuffing* or *packing box*. This stuffing consists of some material which the steam will rather adapt to its office than injure; leather, which is used for the stuffing or collars of machines never to be subjected to heat, will not answer here; hempen yarn is the material usually employed. The rod of the piston *l*, passes through a stuffing box of the same kind as that of the piston E; and the pistons themselves are surrounded with stuffing.

The cylinder D is surrounded by a case, to keep it from being cooled by contact with the external air. The extremity, or any given point removed from the centre of the great beam, can describe only the arc of a circle; but it is necessary that the piston rod *e* should rise and fall vertically. Newcomen effected this object, by making the end of the beam into the arc of a circle, the radius of which was equal to the distance from the centre of the beam: a chain went over this arc, and was fastened on the higher end of it; this simple contrivance effectually answered his purpose, because in his engine the effective stroke was only downwards; but here, in a double-power engine, where the stroke is both upwards and downwards, a chain would yield in rising, and be altogether unsuitable. An apparatus is therefore used, called the parallel joint, which is easily understood by inspection. By this means the rod *e*, not only rises and falls perpendicularly, but is perfectly rigid, and communicates all its motion to the great beam in each direction of its motion. The connecting rod *g* does not require the same contrivance, because it does not rise and fall perpendicularly; its lower end, with the outer end of the crank, describing a circle: it has therefore only a simple joint, admitting of this deviation.

In order to communicate a rotary motion to the fly-wheel, instead of the crank may be used a contrivance giving twice the rapidity to the fly. For this purpose, on the outside of the axis of the fly, where the crank is shewn in the plate, a small toothed wheel is fixed, and can only be moved with the fly; at the extremity of the rod *g*, and on that side of it which is next the fly-wheel, another toothed wheel is fixed, in such a manner that it cannot turn round on its axis, but must rise and fall with the rod to which it is attached. These two wheels

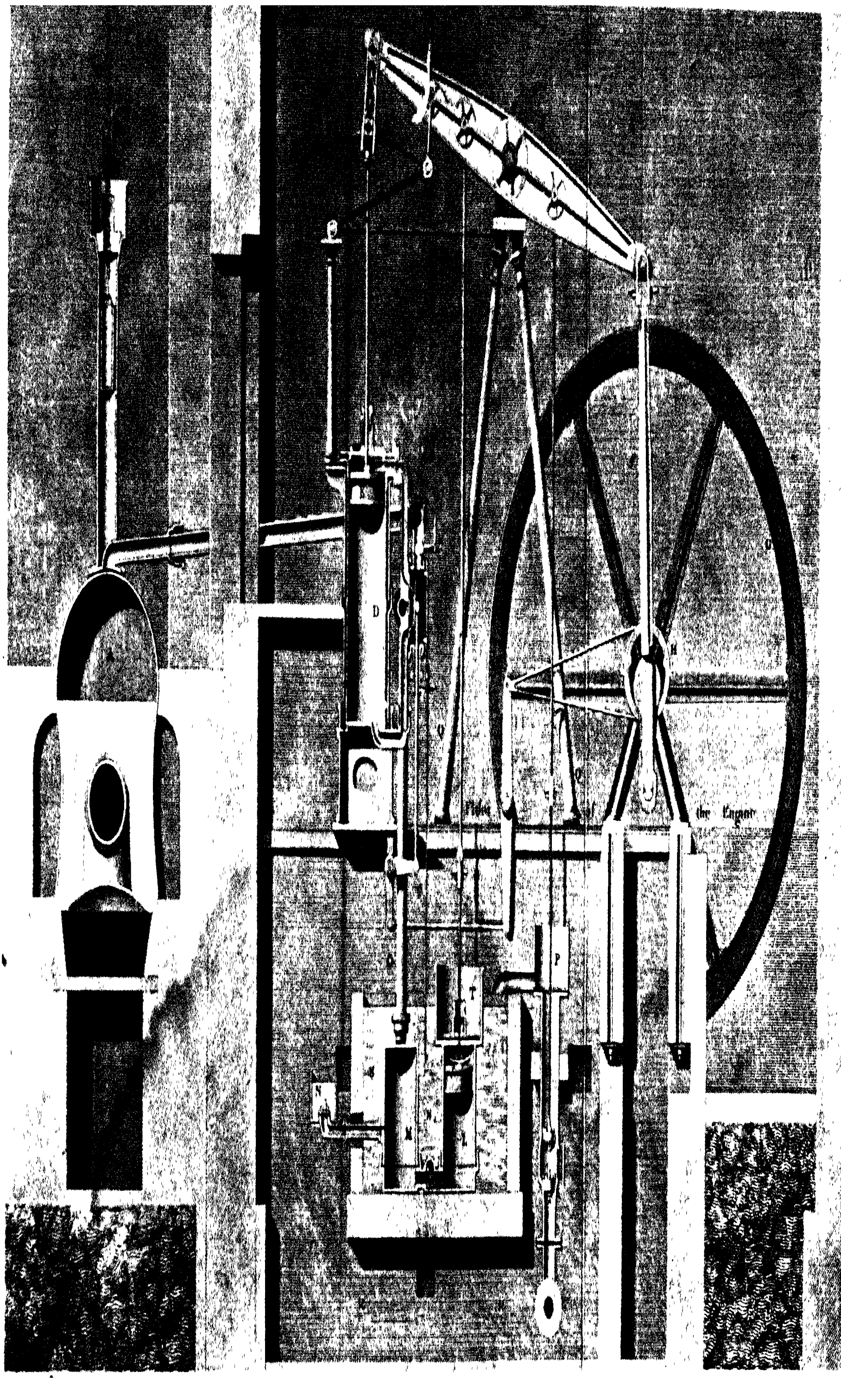
work in each other, and that attached to the connecting rod cannot leave its fellow, because their centres are connected by a strap or bar of iron. When, therefore, the connecting rod rises, the wheel upon it moves round the circumference of the wheel upon the axis of the fly. By this means the fly makes an entire revolution for every stroke of the piston, and some mechanics are apt to think that they are great gainers by such an arrangement: the contrivance is certainly a very elegant one, but with respect to utility, the fact is, that a crank is preferable; for it is more simple, cheaper, and less likely to be out of order, while, if the fly be large enough to receive, with less velocity, all the momentum that can be communicated to it, the effect will certainly not be inferior.

Scarcely a year passes away without bringing forth some new patent for the improvement of the steam-engine. Among the proposed improvements which appear of the most promising nature with regard to the two important points of increasing the power of steam-engines, and lessening the expense of the fuel they require, may be placed the discoveries of Woolf, to which we shall advert as a conclusion of this article, as it comprises a new view of the properties of steam. It had been ascertained by Watt, that the steam which acts with an expansive force of 4 pounds per square inch, against a safety-valve exposed to the atmosphere, after expanding to four times the volume it then occupies, is still equal to the pressure of the atmosphere, but Woolf, carrying his investigations farther, discovered that steam having the force of 5, 6, 7, 8, 9, 10, &c. pounds on every square inch, after expanding to 5, 6, 7, 8, 9, 10, &c. times its bulk, will still remain equal to the atmospheric pressure, provided the cylinder in which the expansion takes place has the same temperature as the steam before it began to expand; and also that this ratio is progressive, and nearly if not entirely uniform, so that steam of the expansive force of twenty, thirty, forty, or fifty pounds the square inch, will expand itself in the degree that expresses this force. Now the advantage to be derived from these facts consists in this, that the augmentation of the steam's expansive force, increases faster than the cost of the fuel or degrees of heat by which it is maintained. At the temperature of 212° of Fahrenheit, the force of steam is just equal to the pressure of the atmosphere; but by increasing the degree of heat, the effects will be obtained, which are detailed in the following table:

Steam predominating over the pressure of the atmosphere upon a safety-valve, if its elastic force be equal to	pounds per square inch, requires to be maintained by a temperature equal to	and at these respective degrees of heat, steam can expand itself to about	times its volume, and continue equal in elasticity to the pressure of the atmosphere.
5	227¼°	5	
6	230½	6	
7	232¾	7	
8	235½	8	
9	237¼	9	
10	239½	10	
15	250½	15	
20	259½	20	
25	267	25	
30	273	30	
35	278	35	
40	282	40	

In the same manner, by small additions of temperature an expansive power may be given to steam equal to from 40 to 400 times its bulk, or in any other proportion; but the strength of the vessels, and care requisite in the management of it, will dictate reasonable limits to the practical application of it. We shall now take so much from the specification of the patent appropriating these discoveries, as may explain the new improvements:

"If," says the Patentee, "the engine be constructed originally with the intention of adopting my said improvement, it ought to have two steam-vessels of different dimensions, according to the temperature or the expansive force determined to be communicated to the steam made use of in working the engine; for the smaller steam-vessel or cylinder must be a measure for the larger. For example, if steam of forty pounds the square inch is fixed on, then the smaller steam vessel should be at least one-fortieth part of the contents of the larger one; each steam-vessel should be furnished with a piston, and the smaller cylinder should have a communication both at its top and bottom (top and bottom being here employed merely as relative terms, for the cylinders may be worked in a horizontal or any other required position, as well as vertical,) the small cylinder, I say, should have a communication both at its top and bottom with the boiler which supplies the steam; which communications, by means of cocks or valves of any construction adapted to the use, are to be alternately opened and shut during the working of the engine. The top of the small cylinder should have a communication with the bottom of the larger cylinder, and the bottom of the smaller one with the top of the larger, with proper means to open and shut these alternately by cocks, valves, or any other well-known contrivance. And both the top and bottom of the larger cylinder or steam-vessel should, while the engine is at



work, communicate alternately with a condensing vessel, into which a jet of water is admitted to hasten the condensation, or the condensing vessel may be cooled by any other means calculated to produce that effect. Things being thus arranged, when the engine is at work, steam of high temperature is admitted from the boiler to act by its elastic force on one side of the smaller piston, while the steam which had last moved it has a communication with the larger steam-vessel or cylinder, where it follows the larger piston now moving towards that end of its cylinder which is open to the condensing vessel. Let both pistons end their stroke at one time, and let us now suppose them both at the top of their respective cylinders, ready to descend; then the steam of 40 pounds the square inch entering above the smaller piston, will carry it downwards, while the steam below it, instead of being allowed to escape into the atmosphere or applied to any other purpose, will pass into the larger cylinder above its piston, which will take its downward stroke at the same time that the piston of the small cylinder is doing the same thing, and while this goes on, the steam which last filled the larger cylinder, in the upward stroke of the engine, will be passing into the condenser to be condensed during the downward stroke. When the pistons in the smaller and larger cylinder have thus been made to descend to the bottom of their respective cylinders, then the steam from the boiler is to be shut off from the top and admitted to the bottom of the smaller cylinder, and the communication between the bottom of the smaller and the top of the larger cylinder is also to be cut off, and the communication to be opened between the top of the smaller and the bottom of the larger cylinder; the steam, which in the downward stroke of the engine filled the larger cylinder, being now open to the condenser, and the communication between the bottom of the larger cylinder and the condenser shut off; and so on alternately, admitting the steam to the different sides of the smaller piston, while the steam last admitted into the smaller cylinder passes alternately to the different sides of the larger piston in the larger cylinder, the top and bottom of which are made to communicate alternately with the condenser.

"In an engine working with the improvements which have been just described, while the steam is admitted to one side of the piston in the smaller cylinder, the steam on the other side has room made for its admission into the larger cylinder, on one side of its piston, by the condensation taking place on the other side of the large piston which is open to the condenser; and that waste of steam which takes place in

engines worked only by the expansive force of steam, from steam passing the piston, is prevented; for all the steam that passes the piston in the smaller cylinder is received into the larger.

Various modifications of the invention are then pointed out by the Patentee, to suit particular occasions or convenience; and with respect to the important point of preventing danger from the employment of highly rarefied steam, he observes in the specification of his second patent: "I have found out and invented a contrivance, by which the temperature of the steam-vessel or working cylinder of a steam-engine, or of the steam-vessels or cylinders where more than one are used, may be raised to any required temperature, without admitting steam from the boiler into any surrounding receptacle, whether known by the name of a steam-case or any other denomination That is to say, instead of admitting steam of a high temperature into such receptacle or steam-case, which is always attended with a risk of explosion proportioned to the elasticity of the steam employed, I put into the said surrounding receptacle, or case, oil or the fat of animals, or wax, or other substances capable of being melted by a lower temperature than the heat intended to be employed, and of bearing that heat without being converted into vapour: or I put into the said case or cases mercury or mixtures of metals, as of tin, bismuth, and lead, capable of being kept in a state of fusion in a lower temperature than that intended to be employed in working the steam-engine: and I so form the surrounding case or cases as to make it or them admit the aforesaid oil, or other substance employed, to come into contact not only with the sides of the steam-vessel or vessels, or working cylinder or cylinders, but also with the bottom and top of the same, so that the whole may be as much as possible maintained at one uniform temperature: and this temperature I keep up by a fire immediately under or round the case or cases that contain the aforesaid oil or other substance, or by connecting the said case or cases with a separate vessel or vessels, kept at a proper temperature, filled with the oil or other substance made use of as aforesaid. In some circumstances, or whenever the same may be convenient or desirable, I employ the fluid metals, or mixtures of metals, in the part of the case or vessel exposed to the greatest action of the fire, and in the parts less exposed to the action of the fire, I put oil, or other substances capable of bearing the requisite heat without being converted into vapour.

"By this arrangement and method of applying the surrounding heat, I not only obviate the necessity of employing steam

of a great expansive force round the steam-vessel or vessels, or the working cylinder or cylinders, as already mentioned, to maintain them at the temperature required, but I am enabled to obtain from steam of a comparatively low temperature, or even from water itself, admitted into the steam-vessel or vessels, all the effects that can be obtained from steam of a high temperature, without any of the risk with which the production of the latter is accompanied, not only to the boiler and other parts of the machinery, but even to the lives of the workmen; for such low steam, or even water (but in every case steam is preferable) being admitted into a steam-vessel or vessels, or working cylinder or cylinders, kept at the requisite higher temperature by the forementioned means, will there be expanded in any ratio required, and produce an effect in the working of the engine, which cannot otherwise be obtained but at a greater expense of fuel, or with the risk of an explosion. By this means I can make use of steam expanded in any required ratio, or of any given temperature, without the necessity of ever having the steam of any greater elasticity than equal to the pressure of the common atmosphere.

"Another improvement which I make use of in steam-engines, consists in a method of preventing, as much as possible, the passage of any of the steam from that side of the piston which is acted upon by the said steam to the other side which is open to the condenser; and this I effect in those steam-engines known by the name of double-engines, by employing upon or above the piston mercury or fluid metal or metals in an altitude equal to the pressure of the steam. The efficacy of this arrangement will appear obvious, from attending to what must take place in working such a piston. When the piston is ascending, that is, when the steam is admitted below the piston, the space on its other side being open to the condenser, the steam endeavouring to pass up by the side of the piston is met and effectually prevented by the column of metal equal or superior to it in pressure, and during the downstroke no steam can possibly pass without first forcing all the metal through. In working what is called a single-engine, a less considerable altitude of metal is required, because the steam always acts on the upper side of the piston. For single-engines, oil or wax, or fat of animals, or similar substances, in sufficient quantity, will answer the purpose, if another improvement, which constitutes part of my said invention, be applied to the engine, namely, to take care that in either the double or single engine so to be worked, the outlet that conveys the steam to the condenser shall be so posited, and of such a size, that the steam may pass without forcing before it

or carrying with it any of the metal or other substance employed that may have passed by the piston; taking care at the same time to provide another exit for the metal or other substance collected at the bottom of the steam-vessel or working-cylinder to convey the same into a reservoir kept at a proper heat, whence it is to be conveyed to the upper side of the piston by a small pump worked by the engine, or by any other contrivance. In order that the fluid metal or metals used with the piston may not be oxidated, I always keep some oil or other fluid substance on its surface, to prevent its coming in contact with the atmosphere; and to prevent the necessity of employing a large quantity of fluid metal, I generally make my piston of the depth of the column required, but of a diameter a little less than the steam-vessel or working-cylinder, excepting where the packing or other fitting is necessary to be applied; so that, in fact, the column of fluid metal forms only a thin body round the piston. In some cases I make a hollow metallic piston, and apply an altitude of fluid metal in the inside of the same to press its outside into contact with the steam-vessel or working-cylinder.

"It may be necessary, however, to state, that in applying my improved method of keeping the steam-vessels of steam-engines at any required temperature to the engine known by the name of Savary's in any of its improved forms, in which a separate condenser has been introduced, I sometimes employ oil, or any other substance lighter than water, and capable of being kept fluid in the temperature employed, without being converted into vapour, in the upper part of the tube or pipe attached to the steam-vessel; by which means steam of any temperature may be used without being exposed to the risk of partial condensation by the admission of any colder body into the steam-vessel; for the oil, or other substance employed for this purpose, soon acquires the requisite temperature; and to prevent unnecessary escape of heat, I construct of, or line with, an imperfect conductor of heat, that part of the tube or pipe attached to the steam-vessel which may not be heated exteriorly. And further, (as is already the practice in some engines, and therefore not exclusively claimed by me,) I cause the water raised by the engine to pass off through another ascending tube than the one attached to the steam-vessel, but connected with it at some part lower than the oil or other substance employed in it is ever suffered to descend to the working of the engine. The improvement which I have just mentioned, of introducing oil into the pipe attached to the steam-vessel of such engines, may also be introduced without applying heat externally to the steam-vessel; but in this case, part of the effect which would otherwise be gained is lost."

Abstract of Hydrostatics and Hydraulics.

1. A fluid is a body whose particles yield to the least effort of partial pressure.

2. Fluidity is attributed to the agency of caloric, which separates the particles of bodies from each other, and lessens their attraction of cohesion.

3. Water will pass through the pores of gold rather than suffer compression, and appears to be very nearly inelastic.

4. Fluids press *in all directions* equally. It is by the artifice of preventing the regular action of this law, that the heaviest metals may be made not to sink, and the lightest woods refuse to swim in water.

5. A fluid presses in proportion to its perpendicular height, and the base of the vessel containing it, without regard to its quantity. On this property is founded the hydrostatical paradox, where a few ounces of water support a weight of several hundred pounds.

6. By *specific gravities*, are meant the relative weights of equal bulks of different substances.

7. This relative weight is generally compared with water as a standard.

8. A balance constructed purposely for taking specific gravities, is called a *hydrostatic balance.*

9. Instruments for taking the specific gravities of fluids without weighing them, are called *hydrometers.*

10. Platina has of all bodies the greatest specific gravity, and is therefore the heaviest body known to exist.

11. The weight of the quantity of water displaced by a swimming body, is exactly equal to the whole weight of that body.

12. The diving-bell, is a vessel which carries down with it into the sea, a supply of air to support life.

13. The velocity with which water flows out of a vessel, is as the square root of the distance of the aperture from the surface of the water: and is the same with that which would be acquired by a body in falling from a height equal to that between the surface and the aperture.

14. In bended pipes, water will always rise to the level of its source, but a jet of water will not flow so high as the surface of the water in the reservoir which supplies it; nor will it in any case rise higher than 100 feet.

15. When the head of water is not maintained, the quantity discharged by an aperture, will only be one-half of what it would be if the level were always preserved.

16. The velocity of running water is different at different depths; but it is generally about nine-tenths of the superficial velocity.

17. A wave runs its breadth in the time of two vibrations of a pendulum equal to one-fourth of the transverse length of the wave's two sides.

18. The thinnest coating of oil will prevent the effect of wind upon the sea.

19. A sucking-pump depends on the pressure of the atmosphere, and will only raise water to the height of 33 feet.

20. The lifting and forcing pumps will raise water to any height, if the force be sufficient.

21. An *air-vessel* is added to a forcing-pump, to equalize the stream.

22. A pump may be so constructed that it may be used occasionally as a fire-engine.

23. In De la Hire's pump, a constant stream of water is produced by the use of two barrels.

24. The screw of Archimedes is a tube wrapped round a cylinder in the form of the thread of a screw. When used, it is placed in an angle with the horizon of between 45 and 60 degrees.

25. The spiral pump, is a tube coiled round a cylinder with the successive coils upon itself. Its axis is horizontal, and it is connected with a vertical pipe, through which the water is raised.

26. A rope pump, which consists of a rope rapidly revolving over two pulleys, one of which is at the top and the other in the water of the well, is useful for drawing water from great depths.

27. A stream of water passing through a vertical pipe with several lateral apertures, will carry along with it a quantity of air; and if it fall upon a block of stone in a covered receiver, from the bottom of which the water can pass off, in rebounding from the stone, the air will be separated, and from its lightness rising upwards, will be forcibly driven out of a pipe placed for that purpose, and thus a *blowing machine* will be obtained.

28. A siphon acts from the pressure of the atmosphere, and its shorter leg must never exceed the length of 33 feet.

29. The Marquis of Worcester proposed, but Captain Savary was the first person who employed, steam, as a motive force, in large works.

30. Newcomen, who invented the steam-engine, employed steam almost exclusively as a means of producing a vacuum; and the pressure of the atmosphere was his motive force, which was therefore exerted only in the downward stroke of the piston.

31. Watt doubled the power of steam-engines, by using steam both to raise and depress the piston, so that both the upward and downward strokes were rendered effective.

32. Woolf discovered the means of saving much fuel, by the use of highly rarefied steam.

AEROSTATION.

The principles and practice of the art of navigating through the atmosphere, is called Aërostation.

The general term for the machines used in this kind of navigation, is that of *aërostats*, or *aërostatic machines*; but those which are of a spherical figure, and filled with gas, are better known by the name of air-balloons. The person who takes a voyage in an aërostat is called an *aëronaut*.

The art of ascending into and navigating through the air, appears at all times to have been an object of fond speculation; but the most exact inquiry has not shewn that it was any other than a romantic hope till so lately as the year 1782. The first aërostatic attempts were directed towards an imitation of the motion and flight of birds; but these proved abortive, when muscular exertion was depended on, because the muscles which could be brought into action, were altogether insufficient to give motion to wings of a suitable size; and when machinery was thought of, the weight of materials and complexity of construction necessary, appeared to be insurmountable barriers to success. Still there was one avenue to the object of pursuit, to which the common and well-known principles of hydrostatics appeared to direct the way, though it had been of all others the most neglected; this was the obvious one, that any body which is specifically, or bulk for bulk, lighter than common air, will rise and swim in it, and submit to the action of the wind; therefore if any body could be found which was in any considerable degree lighter than air, by making it of a sufficient size, a person might attach

himself to it, and float along with it. But as air was considered the lightest of all things, there appeared little reason to believe that such a discovery would be made, till, in the year 1766, Cavendish announced to the world, that the gas, now generally called hydrogen, but at that time called inflammable air, was at least seven times lighter than common air. In consequence of this discovery, it occurred to Dr. Black, and he suggested the idea in his lectures, in 1767 or 1768, that if a bladder, sufficiently light and thin, were filled with this air, it would form a mass so much lighter than the same bulk of atmospheric air, that it would float in the latter. He proposed to use the allantois of a calf, for this purpose, but other avocations prevented his subsequent attention to this subject. Reflecting on the remarks of Dr. Black, Cavallo, about the commencement of the year 1782, made several experiments to elevate a bag filled with hydrogen gas; he tried bladders, the thinnest and largest that could be procured; but though cleaned with great care, and every superfluous membrane scraped off, they were found somewhat too heavy for the purpose. He also tried bags of the finest China paper, of such a size that, had it been possible to fill them with the gas, their ascension would have been certain; but the experiments failed, the reason of which was, that though common air would not pass through this paper, hydrogen gas passed through it like water through a sieve. In short, he was completely successful only in filling soap-bubbles with the gas, which was easily done by pressing small quantities of the gas out of a bladder, while a small pipe from the bladder was immersed in a solution of soap in water; these bubbles rapidly ascended in the ambient air, and they may be considered as the first inflammable air-balloons that were ever exhibited. Cavallo read to the Royal Society the paper in which he gave an account of his experiments, on the 20th of June, 1782.

In the last-mentioned year and month, but unknown to the English philosophers, two brothers, Stephen and Joseph Montgolfier, paper manufacturers at Annonay, about 36 miles from Lyons, in France, conceived ideas that led in a short time to the practice of aërostation on a great scale. Taking notice of the ascent of smoke and vapours, it struck them, that if a cloud could be enclosed in a bag, a floating vehicle would be immediately formed: their attention was therefore directed to the most feasible method of accomplishing this purpose, or something equivalent to it, and the first experiment was made at Avignon, by Stephen, the eldest of the two brothers, towards the middle of November, 1782. He prepared a bag of fine silk, in the shape of a parallelopipedon; its capacity was

about forty cubic feet, and he applied to its aperture burning paper, which rarefied the air, and thus formed in it a kind of cloud; when the bag became in a good degree inflated, he beheld with high satisfaction, that it ascended rapidly to the ceiling. Encouraged by this success, he subsequently made several experiments in the open air, in conjunction with his brother, and on the 5th of June, before a large assemblage of people, exhibited the powers of a machine of great magnitude. The capacity of the new aërostat was equal to about 23,430 cubic feet, and when inflated, it measured 117 English feet in circumference. It was formed of linen, lined with paper; its shape was nearly spherical, and when filled with air at half the density of common air, it was estimated to be capable of lifting about 490 pounds besides its own weight, which, with a wooden frame, sixteen feet in surface, that distended the mouth of it, was equal to 500 pounds more. It was suspended, in a flaccid state, on a pole 35 feet high, straw and chopped wool were burnt under the opening at the bottom, and the smoke, as it was then chiefly supposed to be, which entered it, distended it in all its parts, and it ascended with such velocity, that in less than 10 minutes it reached the elevation of 6000 feet. A breeze carried it in a horizontal direction to the distance of 7668 feet, and it then fell gently on the ground. Balloons of this description were afterwards called *Montgolfiers*.

The Brothers supposed that the ascent of their machine was owing to the peculiar nature of a gas disengaged from burning substances, and which was lighter than common air, whereas the real cause was simply the rarefaction superinduced by heat. By the addition of one degree of heat, of Fahrenheit's scale, air expands about one four-hundredth part; and about 435 degrees of heat, will just double the bulk of a quantity of air.

The intelligence of the Montgolfiers' experiments no sooner reached Paris, than it engaged the attention of philosophers there, and improvements were immediately suggested. As in the experiments which had hitherto been made, the gas employed was only about half the density of common air, it was justly inferred, that inflammable air, which they estimated at an eighth or a tenth part of that of common air, would be still more suitable. They constructed a globular vessel of lutestring, which was rendered impermeable to the subtile gas, by a varnish of elastic gum. It was thirteen feet in diameter, and had only one aperture, like the neck of a bladder, to which a stop-cock was adapted. When it went up, it was 35 pounds lighter than the same bulk of common air. This machine

from its shape, was called a balloon; and afterwards all machines for the same purpose were called *air-balloons*. On the 27th of August, 1783, it was carried to the Champs de Mars, and in two minutes from the time of its being disengaged from the cords, it arose to the height of three thousand one hundred and twenty-three feet. After having floated about three quarters of an hour, it fell in a field about 15 miles distant from the place of ascent. Its fall was owing to a rent, occasioned by the expansion of its contents, under a much diminished atmospheric pressure.

The use of rarefied air-balloons, was nevertheless not yet superseded; several brilliant experiments were tried with them, and at last Pilatre de Rozier gave new zest to the admiration they excited, by the intrepid offer of becoming, in one of them, the first aërial navigator. A splendid machine was constructed for this purpose, in the Fauxbourg St. Antoine, by the younger Montgolfier, who was then at Paris. It was of an oval figure; its diameter was about 48 feet, and its height about 74 feet. To the aperture at the bottom was attached a wicker gallery, about three feet broad, with a balustrade about three feet high. An iron grate in which a fire was lighted for inflating the machine, was suspended under the middle of the aperture, by chains which came down from its sides, and port-holes were opened in the gallery, towards the aperture through which, any person who might venture to ascend, could feed the fire on the grate with fuel, and regulate at pleasure the dilatation of the air enclosed in the machine. The weight of this aërostat was upwards of 1600 pounds. On the 15th of October, from the midst of an immense multitude, Rozier ascended in this balloon to the height of 84 feet from the ground, where he kept the machine afloat, for 4′ 25″, by repeatedly throwing straw and wool upon the fire. The farther ascension of the machine was prevented by ropes. By a proper management of the fire, Rozier allowed himself to descend gradually, and on regaining the earth, assured the spectators that he had not experienced the slightest inconvenience during his excursion. He afterwards repeated the experiment several times, in one of which, accompanied by Giraud de Villette, he hovered over Paris about nine minutes, at the height of about 330 feet. In all these experiments, the balloon was secured by ropes; but it was now determined to attempt an unrestricted excursion. Accordingly, the same balloon was removed to La Muette, a royal palace in the Bois de Boulogne; and on the 21st of November, P. de Rozier and the Marquis d'Arlandes, ascended about 54 minutes after one o'clock. Having reached the height of about 280

feet, at an easy and majestic rate of ascent, they waved their hats, as a token of their satisfaction and safety, to the gazing multitude below, and soon after rose too high to be distinguished, but are thought to have attained the height of not less than 3000 feet. When they concluded to descend, they desisted from supplying the fire with fuel, in consequence of which they descended in a field, about 2000 yards from the place of ascent, after having been in the air about twenty-five minutes.

The enthusiasm excited by these aërostatic experiments spread through all ranks, and the Parisian philosophers, supported by adequate subscriptions, determined to attempt an aërial voyage with an inflammable air-balloon. Charles and Robert were appointed to construct this balloon, and they were the first adventurers in it. It was of a spherical form, and measured 27½ feet in diameter. The upper hemisphere was covered by a net, which was fastened to a hoop encircling its middle, and called its equator. From this equator proceeded ropes, by which was suspended a car in the form of a boat, a few feet below the balloon. In order to prevent the bursting of the machine, by the expansion of the gas in an elevated region, a valve opening inwards was made in the upper part of it; a string descended from this valve into the car, and by pulling at it, the gas might be let out: the car was ballasted with sand-bags. On the 1st of December, 1783, the two aëronauts ascended in this balloon from the garden of the Thuilleries, in the sight of a prodigious concourse of people. Having, with a moderately accelerated velocity, attained the height of 600 yards, they made signals of their safety. They descended in a field about 27 miles from Paris, at a quarter past three o'clock; the rate at which they had travelled had been about 15 miles per hour, and they had not experienced the slightest inconvenience. The balloon still containing a considerable quantity of gas, Charles re-ascended alone, and in ten minutes, he estimated his elevation at 1500 toises, (9591¾ English feet.) The pressure of the atmosphere being here greatly diminished, the balloon swelled considerably; he therefore let out some of the inflammable air, after which, as the balloon's power of ascension was increased by the expansion of the gas, in a higher degree than it was diminished by the loss, he rose to a still greater height. The barometer, which at his departure stood at 28 inches four lines, had now fallen to 18 inches 10 lines; whence it was calculated that he had ascended to the height of 9745 English feet. The thermometer, from about 47 degrees of Fahrenheit's scale, had sunk to 21 degrees. He continued in the air about 33 minutes, and by occasionally pulling the string of the valve at the top, to let out the gas, he descended about three miles from the

place of ascent. The only inconvenience he had experienced, was from a dry sharp cold, and from a pain in one of his ears and a part of his face, which he ascribed to the dilatation of the internal air.

In January, 1784, Joseph Montgolfier constructed the largest balloon that has been witnessed, and with six other persons, among whom was the gallant Rozier, ascended in it. It was 131 feet in height, and 104 feet in diameter. It was formed of a double covering of linen, with three layers of paper between, and strengthened with strings and ribbons. It contained about 540,000 cubic feet of rarefied air, and its weight, including the gallery and passengers, was 1600 pounds. Notwithstanding the care exerted to make this machine strong enough, its descent to the ground was rendered inevitable from the rents it received; one of which in a vertical direction was upwards of 50 feet in length. In its descent, when about 600 feet from the ground, its velocity was considerably accelerated; and 60,000 people hastened to the spot, full of apprehension, and impatient to know the fate of the adventurers. These were, however, all handed out of the gallery in perfect safety.

The brilliant dawn of a new art, which had thus appeared in France, was soon extended to the rest of Europe, and everywhere excited a lively interest and emulation. In London, the first public experiment with an inflammable air-balloon, was undertaken by Count Zambeccari, an Italian, on the 25th of November 1783; this balloon was 10 feet in diameter: but the first aërial voyage performed in England was by Vincent Lunardi, who ascended from the Artillery Ground, London, on the 15th of September, 1784, with an inflammable air-balloon 33 feet in diameter, made of oiled silk. He set off about five minutes after two o'clock, and arrived at Collier's Hill, five miles beyond Ware in Herefordshire, at 25 minutes after four. The thermometer, in the course of his voyage, stood as low as 29 degrees.

The spirit of enterprise for these undertakings being now at its height, aërial voyages in various quarters were undertaken in great numbers, and the public journals were continually furnishing new accounts of the adventurers. Even the common people and children caught the enthusiasm of the moment, and at night, in London and other parts, little Montgolfiers, made of paper, were often seen traversing the air in the direction of the wind. Many of the great undertakings were in themselves highly worthy of note, but in a collective view they would lose their interest by their resemblance to each other; we shall therefore notice only one or two of the most remarkable. In France, on the 15th of July, 1784, the Duke de

Chartres, and the two brothers, Charles and Robert, ascended with an inflammable air-balloon from the park of St. Cloud, at 52 minutes past 7 in the morning. This balloon was of an oblong form, measuring 55 feet by 34. They remained in the atmosphere about 45 minutes, and descended only a little way from the place of ascension; but the incidents of their voyage are the most singular upon record: The large balloon contained a smaller one filled with common air, the intended use of which was to regulate their ascent and descent without the loss of either inflammable air or ballast. At the place of ascension, the barometer stood at 30.12. In three minutes they were enveloped in a dense vapour, which prevented them from seeing the earth. In a situation thus terrific and sublime, they were attacked by a kind of whirlwind, which in a moment turned the machine three times from the right to the left; and the shocks they suffered entirely prevented them from using the oars and helm they had provided for guiding themselves. Never, in their apprehension, did a more dreadful scene present itself to any eye, than that in which they were involved. An unbounded ocean of shapeless clouds rolled beneath, and seemed to forbid their return to the earth, which was still invisible, and the agitation of the balloon became greater every moment. They cut the cords that held the interior balloon, which consequently fell on the bottom of the external balloon, just over the aperture of the tube that went down to the boat, and stopped up that communication. A gust of wind from below drove the balloon upwards, to the extremity of the vapour, where the appearance of the sun shewed them the existence of nature: but they were now assailed by other fears; for the heat of the sun, and the diminished pressure of the atmosphere, caused so great a dilatation of the gas in the balloon, that they expected it to burst. They introduced a stick through the tube, to remove the inner balloon which covered its orifice, but the pressure of the dilated gas upon this balloon was so great as to render this impossible. They therefore continued to ascend, and their danger to become greater, till the barometer stood at 24.36 inches, which indicated a height of about 5100 feet above the surface of the earth. In this extremity, to prevent their total destruction by the bursting of the balloon, their only hope was, that a gash cut in it would not spread so far as to be dangerous by letting out the gas too rapidly. Accordingly, the Duke himself, in his earnestness to secure his object, made two holes in the balloon, with one of the spears of the banners. These holes instantly became a rent of seven or eight feet. They now descended rapidly, and as soon as they came in sight of the terraqueous

globe, they perceived themselves to be descending into a lake, but the celerity with which they threw out about 60 pounds weight of ballast, a little protracted their flight, and caused them to descend about 30 feet beyond the edge of the water. They were none of them injured.

Among the number of those whom curiosity or the hope of gain by the exhibition induced to become aëronauts, Jean Pierre Blanchard, a Frenchman, much distinguished himself. This person had long been desirous of flying, but prevous to the discovery of balloons, his experiments had been directed towards the invention of mechanical contrivances for that purpose. The new principles, therefore, proved exceedingly gratifying to him; and having constructed an inflammable air-balloon, 27 feet in diameter, he had in a short space of time performed five voyages of the ordinary description. Having thus become a veteran in the service, he determined upon an enterprise, which, at the time it was undertaken, appeared to be one of the most daring that the mind of man could conceive: this enterprise was to cross the channel between Dover and Calais. The balloon he used was the same that he had always hitherto employed. Dr. Jefferies, an American, accompanied him. About one o'clock, on the 7th of January, 1785, with a gentle wind about N. N. W. they rose from the cliff before Dover Castle. The day was remarkably fine, and Dr. Jefferies describes with rapture the prospect they enjoyed. On one side appeared the formidable breakers on the Goodwin Sands; on the other, in the country at the back of Dover, they counted thirty-seven towns and villages. At 50 minutes past one, they found themselves descending, in consequence of which they threw out half their ballast, which at first consisted of three bags of sand weighing ten pounds each. They had now lost sight of Dover castle, and had accomplished about one-third of their journey. Finding, by the rising of the mercury, that they were descending again, they threw out the remainder of their ballast and a part of their books; they then rose again, and were soon half way. At a quarter past two, again perceiving themselves to descend, they threw the remainder of their books into the sea. At twenty-five minutes after two, they had passed over three-fourths of the channel, and were solaced by an enchanting view of the French coast. Still they were in some danger, for their balloon descended; they therefore threw away the refreshments they had provided, also the oars or wings of the boat, and other articles. "We threw away," says Dr. Jefferies, "our only bottle, which, in its descent, cast out a steam like smoke, with a rushing noise; and when it struck the water, we heard and felt the shock

very perceptibly on our car and balloon." The descent of their balloon still alarmed them, and they began to throw away their clothes. As a last resource, they were going to fasten themselves to the cords, and cut away their car, but at this critical juncture, while yet four miles from the French shore, they perceived themselves to be rising. In a short time, they were greeted by a magnificent prospect, including Calais and twenty other towns and villages. At three o'clock, they passed over the high grounds about midway between cape Blanc and Calais, and descended at last in the forest of Guinnes. None of Blanchard's excursions, which in a short time afterwards amounted to thirty or forty, remunerated him so well as this. The king of France presented him with a purse of 12,000 livres, and assigned him a pension of 1200 livres a year.

The adventurous Pilatre de Rozier, who, the reader will recollect, was the first aëronaut, was one of the first whose temerity cost him his life. He had projected and executed the plan of using both an inflammable air-balloon and a Montgolfier in conjunction. The inflammable air-balloon was to be uppermost; and suspended by ropes, at the distance of several feet below it was the rarefied air-balloon, below which, in the usual manner, were suspended successively the grate for the fire, and the gallery for the passengers. By a proper regulation of the fire, it was expected they could raise or depress the whole, without being under the necessity of losing any of the hydrogen from the upper balloon. The inflammable air-balloon was of varnished silk, and 37 feet in diameter; the other was of strong linen, and only 10 feet in diameter. They ascended on the 15th of June, 1785: after they had been in the air about twenty minutes, having only a feeble and changeable wind, and only three-quarters of a mile from the place of ascension, their actions displayed an anxiety to descend, by letting out the inflammable air, while at the same time the balloon containing it was observed to be much expanded. In a moment after, the inflammable air-balloon was discovered to be on fire, and to collapse, upon which the two passengers, Rozier and Romain, were precipitated with tremendous rapidity to the earth. The former appeared to be quite dead when he was taken up; the other had some faint signs of life, but expired almost immediately. Upon examination, the lower balloon was found to be entire, but the upper one was much burnt. It appears, therefore, to have been the sparks, or perhaps some considerable piece of fire, which having flown upwards, attached itself to the inflammable air-balloon, till it pierced it, when the gas took fire, and the melancholy catastrophe ensued.

Crosbie ascended at Dublin, on the 19th July, 1785, with a view of crossing the channel to England. Having discharged some gas, at a great height, he was driven upon the sea, where, his balloon serving the purpose of a sail, he moved before the wind with the regularity of a ship, till overtaken by some vessels dispatched after him, and conveyed to Dunleary. Three days afterwards, Major Money ascended at Norwich, and after having been blown about for two hours, he dropt into the water. During seven hours of amazing exertion, he continued to keep himself above water; but his weakness had become extreme; and the curtain of despair had cut off hope, when he was descried and taken up by a revenue cutter.

Blanchard, in his first, and perhaps in all his subsequent voyages, attached to his balloon, a machine called a parachute. This machine, the name of which denotes the *breaker of a fall or shock*, when opened, resembles a large umbrella. Though Blanchard appears to have been the first who adopted it, and was probably the inventor of it, yet Garncrin appears to be the first human being who descended by such means. Blanchard, had, however, proved its effects on a dog, which came down safely. Garnerin performed the voyage alluded to on the 21st of September, 1802, at London. The balloon was one of those filled with inflammable air, which had now become the only kind used; it was covered with a net in the usual manner, and from a net proceeded ropes, which united in a common joining under the centre of the balloon. From this point of union, proceeded a single rope, which was fastened to the basket for the reception of the aëronaut, after the parachute apparatus had been arranged. The parachute consisted of a sheet of canvass 30 feet in diameter. A number of ropes were fastened at regular intervals to the edge of it, and at their other end terminated in a common joining under its centre, whence shorter ropes proceeded, the extremities of which were fastened to the basket. Through the centre of the parachute, and the ropes dependent from it, passed the only rope which connected the balloon and the basket, and it passed through tin tubes, not only to prevent its entanglement with other ropes, but to keep the parachute at a suitable distance from the basket. In ascending, the parachute closes, like an umbrella unfurled; but during a rapid descent it would open out, by the resistance of the atmosphere. The day of Garnerin's ascent was the finest and clearest imaginable, yet, at the moment when, under circumstances thus favourable to vision, he was at a height so immense, as to be scarcely discerned by any of the vast concourse

of people, of whom he had taken his leave only eight minutes before, he boldly cut the rope that connected him with the balloon, and trusted to his parachute for safety. At first he descended with prodigious velocity, but as soon as the parachute had opened, the descent was very gradual. One circumstance, however, occurred, which appeared alarming; the parachute did not descend perpendicularly, but vibrated like a pendulum, to such a degree, that it and the aëronaut appeared sometimes to be on a level. But these vibrations diminished as the adventurer came near the earth, which he reached with a velocity not greater than if he had leaped from a height of three or four feet.

Among the aëronauts of the present time, Sadler, of Oxford, is the most distinguished; he has been in the habit of taking aërial excursions, at different periods, for the last twenty-eight years, in balloons contrived by himself; and with the record of a late excursion of his we shall close this view of the practice of aërostation. He had, in the early part of 1812, declared his resolution to attempt to cross the channel from Ireland to England; and accordingly this astonishing act of intrepidity was performed early in October of that year. The bold adventurer ascended from Belvidere Grounds, Dublin, about one o'clock, with a moderate wind at south-west, and in a gradual and majestic style left the shores of Ireland, amidst the blessings, the prayers, and the plaudits of an immense throng, expressed on all sides with the eloquence and energy characteristic of the people of that country. For some time the wind favoured him, but afterwards began to vary, and he hovered about, having the Isle of Man, the Isle of Anglesea, and Ireland, all in view. He was then carried in a direction towards Liverpool, and about half past four, had a distinct view of Bidston Light-house, about four miles from that port, which he then confidently expected to reach in about half an hour. By the changing of the wind, however, he was carried completely out of sight of land, and now finding night coming on, and that he must spend it in the air, unless he could avail himself of the assistance of some vessel, he descended to the surface of the water in the sight of five sail, but as they took no notice of him, he re-ascended; and after a considerable time came down again upon seeing three others. He was now perceived; but encountered considerable difficulty, and was almost drowned by the dragging of the balloon, before he could be got on board a Mank's fishing-boat, which took him up in the dusk of the evening. At eight o'clock the next morning he was put on board and kindly entertained by the commander

of the Princess frigate, lying in the river Mersey, opposite Liverpool, at which place he landed shortly afterwards.

No discovery has ever been made, which drew after it a more general admiration, or excited more extravagant hopes of utility to man, than the art of aërostation. It was no sooner announced, than already, in the imaginations of many, countries were connected, and commercial intercourse maintained, with unheard of advantages, while philosophy was to receive vast treasures of new facts to extend her borders. How few of these great expectations, after a lapse of more than thirty years, have been realized; and how little has been added to the real knowledge or convenience of life, will be discovered from a review of the most interesting facts that the various voyages which have been performed have brought to light. Let it, at the same time, be duly observed, that the art is still in its infancy, and that the intimate, though not always soon-discovered connection between one fact or branch of knowledge and another, equally forbid us to consider in vain, the exertions already made, or those which may yet be required, before any decisive advantages are derived from aërostation.

Of the various circumstances observed by aëronauts during their voyages, when the apprehension of their safety has ceased, none impresses them so strongly as the stillness that reigns around; with some few exceptions, they hear no wind, whatever may be its violence; nor perceive their motion, whatever may be its rapidity. To account for this, it must be considered, that the air is, with respect to them, at rest, for they move at the same rate with it. It is also remarkable, that they never experience any sickness or giddiness. In one instance, the aëronaut, after his descent, was affected with a temporary deafness, but the wet and cold which he had experienced, would probably have had the same effect upon him in a terrestrial journey. Difficulty of respiration has never been an object of notice. Of all methods of travelling, that in a balloon appears to people in general to be the most unsafe; but this is a conclusion drawn from a cursory view of the subject; the accidents which have happened, particularly those which have terminated fatally, are extremely few in number; and may be attributed to the want of precautions which are easily observed: we have seen even that a rent of 50 feet long, in a Montgolfier, produced no disaster. It should also not be omitted, that voyages have been performed in all weathers, and at all seasons

of the year, and that lightning, which had been dreaded as a potent enemy, has never interposed; upon the whole, it appears probable, that a voyage in a balloon is not more likely to endanger the personal safety of an individual, than a voyage from England to Ireland on the sea.

The longest aëronautic excursion ever taken was by Blanchard and the chevalier de L'Epinard, from Lisle; they traversed a distance of 300 miles. The greatest height ever attained in this way, appears to have been by Morveau and Bertrand, who, from Dijon, ascended to the height of 13,000 feet.

The use of wings, rudders, oars, and every other means that have yet been thought of, to direct the course of a balloon, in opposition to the wind, or even obliquely to its course, have proved entirely unsuccessful. The failure of repeated attempts of this kind, and, in consequence, the apparent futility of the hope that they would ever succeed, proved a severe blow to the fame of the art.

But slender additions have been made to science, from the observations of aëronauts, sometimes because they have not been furnished with proper instruments, but generally because the individuals were incompetent, and had not philosophy, but their pecuniary interest, in view. It has been found that the air at great heights is rather purer than at the surface of the earth. It has also been observed that there are often different currents of wind over the same place; so that the aëronaut, in ascending, goes in one direction till he has attained a certain height, when he is driven in another, and afterwards probably in a third: hence, when he ascends, he has no certainty of the direction he must submit to. Cavallo speaks of a magnetic experiment, in which it was found that a magnet in the atmosphere, would not hold nearly so much as at the surface of the earth. The Abbé Bertholon used small balloons for exploring the electricity of the atmosphere, to which purpose they seem well adapted, and may be used in weather too calm to support a kite; a long slender wire was attached to the balloon, and its lower extremity was fastened to a glass stick, or insulated stand; by this apparatus sparks were afforded, and the kind of the electricity ascertained.

The ascending power of a balloon, is equal to the weight by which it is lighter than an equal bulk of common air. Every cubic foot of the inflammable air may be considered equal to 3¼ drams avoirdupoise, which is about one-sixth of the weight of common air. Hence, if the capacity of a balloon be such that it contains 12,000 cubical feet of this gas, its ascending power may be estimated at 12,000 ounces; and therefore the aëronaut, with the boat and all other appendages,

must weigh less than this. An inflammable air-balloon, if twenty feet in diameter, will just suffice for a single person.

In a rarefied air-balloon, or Montgolfier, the air cannot be expected to be above one-third lighter than common air, and a machine of this sort must therefore be in that proportion larger than the other, to have an equal ascending power.

To witness the flight of a large balloon, has an effect upon the mind, as difficult to describe as it is impossible not to feel. So spacious a globe, with the magnificence of the decorations, excite admiration; the apparently precarious situation of the adventurers, raises apprehension; a machine of such extraordinary dimensions, majestically making its way through a medium which is incapable of supporting a feather;—impressions from all these sources combine to form a mingled sentiment of the deepest interest, unlike that produced by any other exhibition of art. Many have not been able to bear the spectacle without shedding tears, others have involuntarily lifted their suppliant hands to heaven, or fallen upon their knees; several have fainted; and at Lunardi's first ascent, a delicate female was so overcome by her feelings that she died upon the spot.

Construction and Mode of filling Balloons.

There are, as already mentioned, two kinds of balloons, viz. those filled with rarefied air, and those filled with inflammable air.

The best form for balloons, of both kinds, is that of a globe, the capacity of which figure is, for its surface, greater than that of any other. Next to a globe, an elliptical or egg-shape should be preferred; for these forms, the longer axis should be horizontal, because that is the direction in which they would naturally float, in order that their centres of gravity may be the lowest possible.

The envelope of large rarefied air-balloons is generally made of strong linen, lined both internally and externally with paper, over which is laid a varnish consisting generally of strongly drying linseed oil. As a precautionary measure against fire, it is usual in the first instance, to prepare the linen, by soaking it in some fluid that will render it less combustible, for example a solution of alum, or of sal ammoniac and size, using one pound of each to every gallon of water; and when the cloth is dry, to paint it over with some earthy colour, and strong size or glue. The fuel should be of a light kind, such as chopped straw, otherwise it will overload the balloon too much. In all cases, however, the quantity of fuel requisite, renders it impossible to take a long voyage in a balloon of this description.

Small rarefied air-balloons are made of paper which has not undergone any new preparation whatever. The paper must be of that kind called tissue or silver paper, and chosen free from the small holes which are often in it; the pieces are united together by means of flour-paste, or gum-water, till a globular bag is formed. A single aperture is then made in it, about ten or twelve inches in diameter, to which is fastened a ring of slender wire, for its regular distention; the wire is fastened by doubling and pasting the edge of the paper over it. Across the diameter of this ring, and fastened to each side of it, passes a straight wire, upon the middle of which is hung a ball of spun yarn, or a spunge dipped in spirits of turpentine. When the spirits are lighted, the balloon inflates by the expansion of the air within it, and when it is at its full size, it is suffered to take its flight.

No kind of stuff has been found so suitable for inflammable air-balloons, as silk, particularly that kind called lutestring. The silk should be woven on purpose, and at the distance of each eighteen inches, both in the warp and woof, should be inserted a strong cord of flax or silk, so as to form squares in the web. By taking this precaution, when a rent is made in the balloon, the length of it will not extend beyond the square in which it commences. To the upper part of the balloon should be adapted a valve opening inwards, to which should be fastened a string, passing through a hole made in a small piece of wood, which is fixed in the lower part of the balloon. The string reaches into the car, so that the aëronaut may at any time open the valve with facility. Those parts of the valve and its frame, which are in contact, are covered with thick, soft leather, and the valve is kept close by a spring.

To the lower part of the balloon, and opening into it, are affixed two pipes, of the same kind of stuff as the envelope. Through these pipes the balloon is filled, and for a balloon of 30 feet they should be about six inches in diameter.

The car or boat of a balloon, for the reception of the aëronaut, should be made of wicker-work, and covered with leather, well painted or varnished. The balloon is covered with a net, made to its shape, and to this net are fastened the ropes which support whatever it is intended to carry up. The net is generally made large enough to cover the greater part of the balloon, though sometimes it covers only half of it; the various cords from it proceed to the circumference of a circle or ring to which they are fastened. From this ring, which is composed of slender pieces of cane bound together, proceed the ropes by which the boat is suspended, at the distance of several feet below the balloon. For the sake of greater strength,

the meshes of the net are made closest at the top, where there is the greatest strain, and very gradually larger lower down.

The silk for a globular balloon, should be cut to a regular pattern made on purpose; the pattern in length should be equal to half the circumference of the balloon, and its sides should be convex in this manner ( ).

The netting and cords belonging to a balloon, are all made either of silk or of the best flax, and soun with the greatest care.

To stop the dragging of a balloon, after it has descended almost to the earth, the aëronaut is provided with two small anchors or grappling irons, which are shaped either like a ship's anchor, or like three fish-hooks tied together. These are thrown out so as to catch hold of trees or other fixed objects.

The hydrogen or inflammable air, for filling balloons, may be procured in a variety of ways; but the best methods are the decomposition of metals by acids, or of water by heat: In the first method, iron turnings or chippings, are mixed with sulphuric acid, diluted with five or six parts of water. Zinc, though more expensive, affords a gas still lighter than that from iron. Iron may be expected to yield about 1700 times its own bulk of gas; or 4½ ounces of iron, the like weight of sulphuric acid, and 22½ ounces of water, will produce one cubic foot of hydrogen gas: 6 ounces of zinc, an equal weight of acid, and 30 ounces of water, are necessary for producing the same quantity.

To obtain hydrogen by the decomposition of water, a coil of iron wire is put into an iron or earthen tube, which is placed across a small furnace, so that it can be kept at a red heat. One end of the tube is connected with a retort containing water, on distilling which, the vapour from it, in passing over the surface of the ignited iron, is decomposed, the iron attracts the oxygen, and the hydrogen issues from the tube in a state of great purity.

The best varnish for the silk of a balloon, is made of elastic gum, or caoutchouc, cut small, and boiled in five times its weight of oil of turpentine, the solution being afterwards boiled for a few minutes with drying linseed oil. This is the varnish adopted by Blanchard; it must be used warm.

The manner in which a balloon is filled, is represented by fig. 1, plate Aërostation, &c. AB is the balloon suspended by a rope passing between the tops of two poles firmly fixed in the ground, and to each of which one extremity of the rope is fastened. These poles are further secured by ropes, which tie them to the ground. From the cane ring, EF, to which

the cords from the netting are attached, proceed other cords, *a b*, &c. to confine the balloon from rising too soon. CC are two tubs or barrels, which are open at the bottom, and are inverted in other larger tubs, which are filled with water. A short brass or tin tube is inserted in the head of each of the tubs CC, and to these tubes are tied the silken tubes *h h*, communicating with the balloon. The casks CC are surrounded by others, so regulated in number and capacity, that they will not require to be more than half filled with the materials for supplying the gas, which by this apparatus is meant to be obtained by the solution of iron or zinc in diluted sulphuric acid. In the top of these casks, are two holes; through one set of which are put in the metal and acid, after which they are stopped by a wooden plug: in the other holes of the barrels are inserted short tubes, into which other tubes are so fitted that they bend into the tubs DD, and being turned up at their lower ends, open into the barrels CC. It will be understood, that all the upper part of the casks, which is not filled with acid and the metal used, will at the commencement of the operation contain only common air. This is, however, soon expelled, by the hydrogen arising from the mixture, and it is not till the hydrogen, so well known by its smell, comes over alone, that the silken tubes of the balloon are tied to the tubes of the casks CC. As the balloon fills, it supports itself without the aid of the rope passing from the upright poles, and soon lifts the boat as far from the ground as the ropes that restrain it will permit. When the operation of filling is completed, the boat furnished with every requisite for the voyage, and the aëronauts seated, the attendants unloose the ropes, and thus launch the machine into the atmosphere.

Fig. 2, is a representation of Garnerin's parachute, expanded; and fig. 3, the same machine in its closed state, as it ascends.

MAGNETISM.

A PECULIAR species of attraction, exerted by bodies called magnets or loadstones, receives the appellation of *magnetism.*

Of magnets there are two kinds, viz. the natural and the artificial. The *natural magnet* is a mineral which strikes fire with steel; its colour is dull, and generally either dark gray, or brown, or nearly black. It is an ore of iron, and derives the name of magnet, from its possessing the singular property of attracting ferruginous substances, with a force entirely independent of the ordinary properties of matter. This power of attraction may be communicated to iron in any state, under a variety of circumstances; and iron possessing it in any considerable degree is called an *artificial magnet* or *loadstone.* Magnetism is an accidental property of iron, which may either possess or be deprived of it without losing any of its essential characteristics as a metal.

Magnetic attraction was till lately supposed to be exerted by ferruginous bodies alone on other ferruginous bodies, and hence the use of the magnet was resorted to, with a view to detect the presence of iron; but some modern investigations render it probable that nickel is also susceptible of it. Richter having made a series of experiments on this metal, considers it more attractable by the loadstone than iron; and Chenevix is of opinion that both nickel and cobalt are really magnetic, and that when this does not appear to be the case, it is owing to their combination with arsenic.

A magnet suspended by a thread, or placed in any situation that leaves it at liberty to move with freedom, turns one part of its surface towards the north pole of the earth, and consequently the opposite part of its surface towards the south pole. Those parts of the surface of a magnet which assume the position stated, are called its *poles;* they are not reversible points, but the pole which is at any time observed to point towards the north, will always point in the same direction, or nearly so; and the like remark must of course apply to the other or south pole.

The attractive properties of the magnet have been known for time immemorial; but it was not till about the close of the twelfth, or very early in the thirteenth century, that its directive property became known. The discovery of it is generally attributed to John de Gioja, a handicraft of Naples, although several authors previous to his time had obscurely intimated

their knowledge of it. Gioja having observed the property by accident in a few magnets, soon extended his researches, and found that it was common to them all, at least at the place where he lived. Sensible of the value of the acquisition the world would obtain, if the property he had thus discovered remained unimpaired by time or place, he made several journeys to various parts of Italy, to prove its immutability, and his inquiries satisfied him that there was no perceptible difference in it, except by the vicinity of masses of iron. The first trial of the directive property of the magnet on the water, consisted in mooring a vessel out at sea in a direction corresponding with that of the magnet; and a boat having a magnet suspended by its centre on a pivot, was dispatched at night in the exact line the magnet pointed out, the consequence of which was, that it arrived at the place where the vessel was at anchor. Such was the origin of the mariner's compass, the inestimable value of which as a guide in crossing the ocean, and trackless deserts, as well as in other circumstances of minor importance, can be more duly appreciated by the supposition of our situation under the want of it, than by any other means.

The magnetic needle does not in general rest exactly in the direction of the meridian of the place where it is observed, consequently not directly north and south. This phenomenon, which is called the *declination of the magnet*, was discovered in the year 1500, by Sebastian Cabot; but Ferdinand, the son of Columbus, asserts that his father had observed it on the 14th of September, 1492. At first it was not doubted, that the magnetic declination was an equal quantity at all times and places; but Gellibrand, an Englishman, discovered that it was variable, and published an account of this discovery in a pamphlet, printed in 1635.—A circle, coinciding with a plane perpendicular to the horizon, and passing through the centres of the poles of a magnet, is called the *magnetic meridian*.

Another property of the magnetic needle, much more singular than that of its declination, is, that when suspended by the point which would be its centre of gravity according to its mass of matter, it does not remain horizontal, but one extremity sinks lower than the other. This is called the *dipping* of the needle or magnet, and it varies in different latitudes. In the southern hemisphere it is the south pole which is depressed; and in the northern hemisphere it is the north pole. At the equator, the needle assumes a position almost correctly horizontal. The dipping of the needle was discovered by R. Norman, who published an account of it in 1581, but he had ascertained the fact a considerable time previously.

If the north pole of one magnet be presented to the south pole of another, the two magnets will attract each other; but if the north pole of one be presented to the north pole of the other, they will repel each other, provided they be suspended by threads, or swimming upon a cork on water, or in any other way at liberty to move with perfect freedom. This is called *magnetic repulsion*.

The middle part of a magnet, exactly between the extremities of the two poles, is possessed of no power either of attraction or repulsion: but if the magnet be divided in the middle, each half will become a distinct magnet; and those parts which were the north and south poles of the single, original magnet, still retaining their character, the extremities formed by the division will be such as to make each half a complete magnet. The neutral point of a magnet is called the *magnetic centre*.

The attraction subsisting between the magnet and iron, is mutual; that is, the iron attracts the magnet as much as the magnet attracts the iron: for when the magnet is fixed, the iron, if at liberty, will move towards it, or *vice versâ;* and when both the magnet and the iron are at liberty, as in the instance of their swimming upon water on a cork or any floating body, they will move towards each other with equal quantities of motion.

The more pure and soft any piece of iron may be, the more forcible is the action of the magnet upon it: and in general the harder and less pure the state of the iron, the less it is acted upon. The impurity of the iron is, however, a greater obstacle than hardness. Thus, though very hard steel submits to the transient application of magnetism with difficulty, it yet receives it with more facility than iron ores, or iron in the state of an oxide; and it is observable, that the higher the degree of oxidation, the more the attraction is diminished. Iron, even in a state of solution, is not deprived of the susceptibility of this kind of attraction.

The magnetic action decreases with the distance from perfect contact; but the rate of this decrease has never been correctly ascertained. Some have supposed it to be in proportion to the squares of the distances; others as the cubes of the distances; while others suppose the ratio of decrease to be still different. This uncertainty has partly arisen from differences in the action of different magnets, and partly perhaps from the inaccuracy of the experiments made with a view to determine the question. We shall here describe the method in which the subject has been investigated, with the actual results. Muschenbroek suspended a cylindrical magnet, 2 inches long, and 16 drams in weight, to one scale of an accurate balance, and under it he placed a cylinder of iron of the same shape and bulk. The following is the force

with which it attracted at different distances, estimated by the number of grains in the opposite scale:

At the distance of 6 inches the attraction was equal to			3	grains,
5	..	..	$3\frac{1}{2}$	..
4	..	..	$4\frac{1}{2}$	..
3	..	..	6	..
2	..	..	9	..
1	..	..	18	..
In contact	..	..	87	..

The facts relative to magnetism are apparently of an extremely anomalous nature; and this will probably remain to be the case until a more extensive and accurate acquaintance with the phenomena gives stability to the theory which reconciles them all.

Magnetic repulsion takes place only between poles of the same name; thus a north pole always repels a north pole; and a south pole always repels a south pole; yet it is observed that when the north pole of a weak magnet is presented to the north pole of a powerful one, an attraction often appears; but when this occurs, it is found that the poles of the weaker magnet have in reality been reversed, and its north pole has acquired south polarity.

Magnetism is transmitted through all bodies, and apparently through those which are the most solid with as much facility as through the most porous; in moving a magnet to and fro under a slice of cork or a plate of gold, the effect upon bits of iron lying upon these substances appears to be the same. And no difference is observed, whether magnetical experiments are tried in vacuo or in the open air. Nevertheless, there are other causes, which render magnetism one of the most mutable of powers. It is weakened by an increase of temperature, but the change is temporary, and cooling restores it again; unless the heat has been very considerable. For example, a white heat almost entirely eradicates magnetism, and iron, while in that state, ceases to be attractable. The iron again acknowledges the magnet when its redness or the radiation of visible heat from it ceases.

Variations in the declination of the magnetic needle, occur at different periods of every day, and with the different seasons of the year; but they are not exactly periodical, nor subject to any law which has yet been ascertained. They are also very observable at the time of the appearance of the Aurora Borealis, or northern lights.—The following axioms with respect to the influences of these causes, have been collected by L. Cotte:

"1. The greatest declination of the needle from the north towards the west, takes place about two in the afternoon; and the greatest approximation of it towards the north, about eight in the morning; so that from the last-mentioned hour till about two in the afternoon, it endeavours to remove from the north, and between two in the afternoon and the next morning, to approach it.

"2. The annual progress of the magnetic needle is as follows:—Between January and March, it removes from the north; between March and May it approaches it: in June it is stationary; in July it removes from it; in August, September, and October, it approaches it: its declination in October is the same as in May; in November and December it removes from the north: its greatest western declination is at the vernal equinox, and its greatest approximation to the north, at the autumnal equinox.

"3. The declination of the magnetic needle is different, according to the latitude: among us, it has always increased since 1657; before that period it was easterly.

"4. Before volcanic eruptions and earthquakes, the magnetic needle is often subject to very extraordinary movements.

"5. The magnetic needle is agitated before and after the appearance of the northern lights: its declination on those occasions is, about noon, greater than usual.

"6. The greater or less appearance of these northern lights is variable: some years this phenomenon is very frequent, in others uncommon: for two or three years they have occurred very seldom.

"7. The northern lights are more frequent about the time of the equinoxes than at other periods of the year.

"8. The phenomenon is almost constant during the long winter in the polar regions, and is more uncommon the nearer the equator.

"9. Southern lights have been observed also in the regions near the south pole.

"10. The northern lights are often accompanied with lightning, and a noise like that of electricity; while the lightning proceeds partly from the middle of the northern lights, and partly from the neighbouring clouds.

The declination of the magnetic needle is at present about 24½ degrees to the westward. In 1657, there was no declination, that is, the needle stood in the astronomical meridian, or due north and south.

The variation of the dip or inclination of the needle, is at the same place, exceedingly small. In London, about the year 1676, the north pole of the dipping needle stood 71° 50″ below the

horizon, and in the year 1775 it stood at 72° 3′: by these observations, therefore, the whole change of inclination, in nearly 200 years, does not amount to a quarter of a degree.

As iron enters more or less into the composition of almost every substance, it may be inferred that those substances which contain it, even in the minutest quantity, will submit to the magnet, if the experiment be conducted with sufficient delicacy. Yet the nature of some of the substances which yield to this power, almost induces a supposition that a variety of bodies besides the ferruginous, may be obscurely the vehicles of it. The authorities for allowing magnetism to nickel and cobalt, have already been adverted to. It may now be observed, that zinc, bismuth, and their ores, are found to be attractable: of the earths, the siliceous evinces the most evident signs of this attraction; and the calcareous the next. Most of the precious stones are attractable, and the garnet so remarkably, as often to acquire a permanent polarity. Most animal and vegetable substances shew signs of magnetism after combustion; even soot is not destitute of this disposition. Soft brass, upon which the magnet has no effect, may be rendered magnetic by hammering. It may be supposed, in this case, that the brass receives some slight quantity of iron from the anvil or the hammer; this may be true where it is hammered in contact with iron, but the effect of the magnet upon it is the same, although hammered with and upon a stone, and it appears to have a connection with its being hardened by hammering; for if the same piece of brass be softened by annealing it, the magnet no longer affects it. Platina, treated in the same manner as the brass just described, exhibits the same effects.

Experiments to discover very minute indications of magnetism, are generally conducted by placing a small quantity of the substance to be tried upon a shaving of cork or a morsel of paper floating upon water, and then bringing a powerful magnet close to it.

Iron dipping into sulphuric acid, instantly becomes more attractable than before; but after its surface has become considerably oxidated, its attractability is rather diminished.—Nitric acid has a similar effect, but not quite in so high a degree. The experiment is tried, by placing the piece of iron in a vessel where the acid may be poured upon it, and in a direction oblique to the magnetic meridian; a nicely suspended magnetic bar is brought near it, and as soon as the acid attacks the iron, the bar will be drawn nearer, and when the effervescence has ceased, the bar will be further off than before.

The position in which a magnet is kept, and the manner in which it is loaded, have an effect upon its power. If it be constantly kept with its north pole to the north, and be loaded with a weight which is gradually increased, it acquires additional magnetism. But in proportion as the position in which it is kept, deviates from the magnetic meridian, and if at the same time it is kept either without a weight, or with too light a one, its power is soon very materially impaired.

In the northern hemisphere, the north pole is considered the most powerful, and in the southern hemisphere the south pole has the advantage; but, in order to render a natural magnet capable of raising the greatest weight possible, an artifice is adopted to render both poles subservient to the lifting of the same load. Thus, let A B, fig. 4, (pl. Aërostation—Magnetism) represent a natural magnet; two pieces of soft iron, *f g*, are adapted to the sides containing its two poles, and project a little over an adjoining side towards each other. These pieces become themselves as magnetic as the stone while they are in contact with it, and a single piece of iron *k*, extending to both the shoulders *h h*, will be supported by the joint force of the two poles. From the piece *k*, when it is designed to improve the magnet to the utmost, any weight may be suspended which can be conveniently increased. A magnet thus provided with iron, is said to be *armed*, and the two pieces of iron are called the *armature*. The armature is generally covered with a brass box, for the purpose of more conveniently lifting or suspending the magnet, and to prevent the separation of the pieces.

Of the Communication of Magnetism.

When a piece of soft iron is in contact with one of the poles of a magnet, it becomes itself magnetical, and, after the subtraction of its own weight, capable of supporting as much as the magnet from which it derives its virtue. If a piece of hardened steel be placed in the same situation, although it exhibits signs of magnetism, yet it exhibits them only in a much lower degree: another difference in the two cases, still more remarkable, is, that the iron almost totally loses its power as soon as it is removed from the magnet, but the effect produced upon the steel is permanent. In either case, the end which has been in contact with the magnet, acquires a polarity opposite to that of the pole by which it was attracted.

From the facility with which iron parts with its magnetism, it evidently becomes of little or no value as an artificial magnet; but hardened steel, from possessing an opposite property, becomes a most suitable material for this purpose; and

accordingly, the chief object of attention is, to render it magnetical in the highest degree. Various processes have been given for this purpose, but Canton's has been esteemed the best. This philosopher, in about half an hour, communicated, to six bars of hardened steel, at first entirely destitute of any magnetic virtue, the utmost power they were capable of acquiring.

In proceeding according to Canton's method of magnetizing, procure a dozen bars; six of them must be of soft steel, each three inches long, a quarter of an inch broad, and one-twentieth of an inch thick, with two pieces of iron, each half the length of one of the bars, but of the same breadth and thickness. The six other bars must be of hardened steel, each five and a half inches long, half an inch broad, and three-twentieths of an inch thick, with two pieces of iron of half the length, but the whole breadth and thickness of one of the hard bars; and let all the bars be marked with a line quite round them at one end. These marked ends are to become the north poles of the respective bars. Then take an iron poker and tongs,* or two bars of iron, the larger they are, and the longer they have been used, the better; and fixing the poker upright between the knees (or rather in the direction of the dipping needle) with its point downwards, hold to it, near the top, one of the soft bars, having its marked end downwards, by a piece of sewing silk, which must be pulled tight with the left hand, that the bar may not slide; then grasping the tongs with the right hand a little below the middle, and placing them nearly in a vertical position, or in the same direction as the poker, let the bar be stroked by the lower end, from the bottom to the top, about ten times on each side, which will give it a sufficient degree of magnetical power to lift a small key at the marked end; which end, if the bar was suspended on a point, would turn towards the north, and is, therefore, called the north pole, and the unmarked end is, for the same reason, called the south pole of the bar.

Four of the soft bars being impregnated after this manner, lay the other two upon a table, parallel to each other, about a quarter of an inch asunder, and between their iron conductors, AB, CD, fig. 5, (pl. Aërostation—Magnetism,) with a north pole and a south pole against each piece of iron;

* Probably the poker and tongs used by Canton were magnetic, otherwise he would not have succeeded.

then take two of the four bars already made magnetical, and place them together, so as to make a double bar in thickness, the north pole of one being even with the north pole of the other; and the remaining two being put to these, one on each side, so as to have two north and two south poles together, separate the north from the south poles at one end by a large pin, and place them perpendicularly with that end downward, on the middle of one of the parallel bars, the two north poles towards its south, and the two south poles towards its north end, (see fig. 6,) slide them backward and forward three or four times over the whole length of the bar, and removing them from the middle of this, place them on the middle of the other bar as before directed, and go over that in the same manner; then turn both the bars with the other side upward, and repeat the former operation: this being done, take the two from between the pieces of iron or conductors, and placing the two outermost of the touching bars in their room, let the other two be the outermost of the four to touch these with, and this process being repeated till each pair of bars has been touched three or four times over, which will give them a considerable magnetical power, put the half dozen together, after the manner of the four, and touch with them two pair of the hard bars, placed between the conducting irons, at the distance of about half an inch from each other; then lay the soft bars aside, and with the four hard ones let the other two be impregnated, holding the touching bars apart at the lower end about two-tenths of an inch, to which distance let them be separated after they are set on the parallel bar, and brought together again after they are taken off. This being observed, proceed according to the method already described, till each pair has been touched two or three times over. But as a bar, by this vertical way of touching, will not obtain the highest power of which it is capable, let each pair be now touched once or twice over, in their parallel position between the conducting irons, with two of the bars held horizontally or nearly so, by drawing at the same time the north of one from the middle over the south end, and the south of the other from the middle over the north end of a parallel bar: then bringing them to the middle again without touching the parallel bar, give three or four of these horizontal strokes to each side. The horizontal touch, after the vertical, will give the bars as much magnetical power as they are capable of receiving, insomuch that they will receive no additional strength, when the vertical touch is given by a greater number of bars, and the horizontal by those of a superior magnetical power. The whole of this process may be

gone through in about half an hour, and each of the larger bars, if well hardened, may be made to lift twenty-eight troy ounces, and sometimes more. The bars thus prepared, will give to a hard bar of the same size, its full virtue in less than two minutes; and they are, for all the uses of magnetism, much more convenient than a natural loadstone, the power of which is insufficient to impregnate hard bars.

When these half dozen bars are not in use, they should be preserved in a case, disposed as shewn by fig. 7, viz. two poles of the same name should never come together, but alternately a north and a south pole, and the two iron conductors, *a b*, should be laid as one bar by the side of them. When their power has by any means been impaired, it may quickly be restored by the method employed in forming them; and if, for any purpose, a much lagger set of bars be desired, they will communicate a sufficient quantity of magnetism to proceed with, and the large bars may by the same method be brought to their full strength. Canton, by this process, communicated magnetic virtue to two large bars, each half an inch square, ten inches and a half in length, and weighing nearly ten ounces and twelve pennyweights, to such a degree, that one of them lifted by one of its ends, seventy-nine ounces and nine pennyweights: and a flat semi-circular magnet, weighing an ounce and thirteen pennyweights, was made to lift, by applying its two ends together to an iron wedge, ninety troy ounces. He could also readily deprive his bars of their magnetism; and change the poles of a natural loadstone, by placing it in an inverted direction, between the contrary poles of his larger bars, laid down at some distance from each other, in the same straight line continued at the distance of about a quarter of an inch from either of the poles, without touching the stone with either of the bars.

The manner in which Canton hardened his bars has been pointed out as particularly excellent, and as contributing to his success: having cut a sufficient quantity of the leather of old shoes into very small pieces, he took an iron pan, which a little exceeded the length of the bars, and was wide enough to admit of two bars side by side, without touching each other or the pan, and at least an inch deep. This pan was nearly half filled with bits of leather, upon which were laid the two bars, with a wire fastened to the end of each, for taking them out: the pan was then quite filled with leather, and placed on a moderate fire, being covered and surrounded with charcoal. The pan being brought to somewhat more than a red heat, was kept about half an hour in that state, and the bars were suddenly quenched in a larger quantity of

water as in common hardening. The length of time prescribed for the steel to remain in the fire, appears to be unnecessary; every purpose of hardening may be answered by taking it out as soon as it has acquired the requisite heat. The iron box is useful, because, by preventing the bars from coming into contact with air while they are heating, it prevents their scaling. The leather cannot be considered an essential article, or at least not superior to charcoal dust in the box; either ingredient is advantageous only as it supplies the steel with a small portion of carbon, rather than suffers any to be abstracted, and thus prevents the steel from degradation. To quench the bars in mercury, would render them harder than water, and probably capable of receiving a stronger and more lasting magnetism; but it must be remembered, that the harder they are rendered, the more they are in danger, from their brittleness, of being broken by accident.

To obtain the combined effect of two poles, without the inconvenience and expense of the armature applied to natural magnets, artificial magnets are sometimes made in a semicircular form, but more commonly in the form of a horse-shoe, as designated by *a b c*, fig. 8, which represents what is called a horse-shoe magnet. To communicate magnetism to a bar of this kind, lay it down upon a table, and place magnetic bars, AB, against its extremities, the south of one bar being placed against that end of the horse-shoe which is intended to be the north; and the north end of the other bar against that which is intended to be the south; a conductor, E, of soft iron, must join the other two ends of the straight bars. Now rub the horse-shoe magnet with bars inclined to each other and meeting at the top, so as to form an angle, as in Canton's method; or use two bars only, as shewn in the figure, and stroke the horse-shoe with them from end to end; or lastly, use another horse-shoe magnet, turning the poles properly to the poles of the new magnet. In any of these methods, the bars AB must not be touched with the magnets passing over the horse-shoe magnet, nor should the touching magnets be separated from the horse-shoe too suddenly.

To magnetize compass needles, the following methods may be used: Provide a pair of magnetic bars not less than six inches in length. Fasten the needle down on a board, and with a magnet in each hand, draw them from the centre upon the needle outwards; then carry the bars to a considerable distance from the needle, and bring them perpendicularly down upon the centre, and draw them over again. This operation,

repeated about twenty times, will sufficiently magnetize the needle, and its ends will point to the poles contrary to those which touched them.

In another method of touching needles—over one end of a combined horse-shoe magnet, of at least two in number, and six inches in length, draw from its centre that half of the needle which is to have the contrary pole to the end of the magnet; raise the needle to a considerable distance, and draw it over the magnet again; this repeated about a dozen times, and the same for the other half, will communicate an adequate portion of magnetism.

Composition magnets are made by the use of iron or steel filings, obtained in the most minute state by washing in water, and made into a paste by kneading them with linseed oil. This paste being moulded into convenient forms, must be exposed upon wood or tiles, in a warm situation, until it becomes dry and firm; it may then be magnetized like steel bars, and will acquire a considerable degree of permanent power.

Every kind of steel does not receive magnetism with equal facility. With some kinds of steel, a few strokes are sufficient to communicate all the power the bars of it are capable of receiving; other kinds receive it reluctantly, and not till after a long operation; and sometimes bars are met with, to which it is impossible to give more than a very low degree of magnetism. In general, the best blistered steel, free from all veins of iron, answers the best. Blistered steel is perhaps better than cast steel, because being drawn out by hammering and rolling, it obtains a longitudinal grain, which is found to be favourable to the circulation of magnetism. Cast steel, on the contrary, from having been in a state of fusion, can only be considered as an aggregation of small particles.

When any bar of steel is found not to acquire so much magnetism as may be expected, the best method of treating it, is to harden it again, with a less degree of heat than before; if it still be defective, it may be hardened at a greater degree of heat than at first: by one of these means an improvement may often be effected.

A magnet employed in the communication of magnetism, rather gains than loses in strength, but it cannot impart a greater degree of power than its own. A combination of weak magnets, it must, however, be evident, from Canton's process of magnetizing bars, will communicate magnetism in proportion to their accumulated power.

When both weak and strong bars are used to magnetize others, it has been usually recommended to apply the weak magnets first, and the stronger in succession, with a view to

prevent the weaker magnets from drawing off some of the accumulated power of the new magnet. But for this precaution there appears not to be a necessity, as no magnet is ever found to lose power by the application of another, in a direction favourable to the reciprocal communication of their virtue.

Every kind of violent percussion, or whatever disturbs or deranges the disposition of the particles of a magnet, weakens its power. A strong magnet has been entirely deprived of its magnetism, by several smart strokes of a hammer. The effect of the hammer is in some measure correspondent to what takes place in shaking a glass tube filled with iron filings; the filings thus inclosed, may be magnetized as if they were a steel bar, and the tube will become a magnet; but when the situation of the filings among themselves is altered, by shaking the tube, the magnetism disappears.

The precaution given for keeping Canton's bars, viz. to allow only opposite poles to be in contact, should be extended to the keeping of magnets in general; for they weaken each other when either their north poles or their south poles are left in contact. It is always proper to leave a single magnet armed, that is, with a piece of iron attached to it.

The bars used for artificial magnets should be completely polished, with their sides and ends perfectly flat, otherwise they will not receive or communicate the maximum of power for their size.

In some instances, magnetism is obtained without the agency of any artificial cause. Thus, if a bar of iron, three or four feet long, be held in a vertical position, or, what is more proper, in the direction of the dipping needle, it will immediately shew signs of magnetism, by attracting light pieces of iron, such as a needle. Upon trying it with a magnet, it will be found that the lower end is the north pole, for it will there repel the north pole of the magnet. If the bar be inverted, the polarity will be instantly reversed; so that in all cases the lower extremity is, in this hemisphere, the north pole: but on the south side of the equator, the lower extremity is always the south pole.

With a bar of hard iron, or of steel, this experiment will not succeed, because such bars acquire magnetism too reluctantly to be influenced by so slight a cause as a temporary change of position.

Bars of iron which have, for a long time, remained entirely or for the most part in a vertical position, are generally found to be more or less magnetical; fire irons, bars of windows, &c. are examples.

If a long piece of iron be made red-hot, and then left to cool in the direction of the dipping needle, it becomes magnetical. It has been observed, that to strike a magnet with a hammer, may deprive it of its magnetism; on the contrary, it is found, that if an unmagnetical bar be struck with a hammer, or rubbed with a file, while held in the position of the dipping needle, it will acquire magnetism. An electric shock produces the same effect; and lightning often renders bars of iron magnetic; but both lightning and the electric shock will destroy the power of magnets already formed.

A circular piece of iron or steel, such as the verge of a watch, may have a north or south pole; and when the verge of a watch happens to acquire magnetism, its constant tendency to one direction has a material influence on the performance of the machine. Varley, having suspected this to be the case, on finding that many time-pieces, of the best construction and unexceptionable workmanship, performed indifferently, took a suspected verge, and placed it upon a piece of cork on water, when he discovered that a certain point in it constantly turned to the north. To satisfy himself still more effectually, he substituted a golden verge for the steel one, upon which the going of the watch became equal to that of any other of the same construction and workmanship. This ingenious discovery evidently points to the conclusion, that steel, though almost universally used, is not a proper material for the verge of a watch: and that many time-pieces, for the defective performance of which the reputation of the makers has suffered, may require only an unmagnetical verge to render them perfect.

Of the Theory of Magnetism.

The only proposition towards the theory of magnetism, which seems placed beyond the reach of doubt, is, that the earth itself acts as a great magnet; and if this be evident, it will scarcely be denied, that all other magnets derive their power and properties from its effects. Supposing the earth to be a magnet, the manner in which it operates, in causing the directive property and inclination or dipping of the needle, is just what might be expected, and may be exemplified by an easy experiment: over the middle of a magnet, LM, fig. 9, (pl. Aërostation—Magnetism,) hold a magnetized needle P, suspended by a fine thread, and so fixed, that if it were removed to a distance from any magnet or iron, it would remain horizontal. In this position, the needle P being equally attracted by both ends of the magnet LM, remains horizontal, but it turns its north pole to the south pole of the magnet,

and its south pole to the north pole of the magnet. (The north pole of the needle and magnet is designated by a transverse mark.) Remove the needle from the situation P to the situation R; and it will cease to be horizontal; the south pole of the needle will incline towards the north of the magnet, and exhibit the phenomenon of the dipping needle. Remove the needle to the situation T, and the same change of position will take place, only it will be the north pole of the needle which will be drawn down to the south pole of the magnet. A globular magnet exhibits this epitome of magnetism in a still more agreeable manner, and a magnet of that kind made for the purpose, is called a terella, or little earth. As the large magnet in this experiment acts upon the needle; so does the earth upon all other magnets. When the centre of the needle is over the centre of the magnet, it corresponds nearly to the situation of any suspended magnet at the equator of the earth, where the attraction from both poles is nearly equal; and where the needle would be exactly horizontal, if the magnetical and geographical poles of the earth coincided; but as this is not the case, the magnetical and geographical equators are differently situated.

That the earth is a magnet also admits of strong collateral proofs: it may be inferred from the vast quantities of ferruginous bodies contained in it, which are often dug up in a magnetical state, and from the magnetism which iron acquires by its position. Yet all this carries us but a very little way towards a complete theory of magnetism, and the difficulties yet in our way are of great magnitude. For example, it is found, that the magnetical poles of the earth change their situation, and this singular circumstance has opened a wide field for speculation. It has been supposed, that the earth contains a detached internal magnet, which has a different motion from that of the earth, though both their axes coincide. This internal loadstone, the advocates of it suppose to be separated from the outer globe or earth by a fluid medium; and to account for the constant variation of the needle westward, they suppose its motion with respect to that of the earth to be such that its north pole revolves from east to west, at the rate of one degree in five years, so as to make a complete revolution in 1920 years. To explain the reason why the motion of the internal loadstone should be less than that of the earth, it is assumed, that the diurnal motion of the earth arose from an external impulse, which was thence communicated internally. This theory has never given much satisfaction; the regularity of motion assigned to the internal loadstone, leaves entirely unaccounted for the frequent variations actually observed; and the attempt

that has been made to supply this deficiency, by supposing that there are within the earth four magnetic poles, which are moveable with respect to each other, looks only like a wild effort to secure a solution, whatever may be sacrificed to obtain it. It seems much more rational to conclude at once, with Cavallo, that the magnetism of the earth arises from the magnetism of all the magnetic substances it contains, whether intermixed with other bodies or not; that the magnetic poles of the earth may be considered as the centres of the polarities of all the particular aggregates of the magnetic substances; and that these principal poles must change their places, relatively to the surface of the earth, according as the particular aggregates of magnetic substances within the earth, are by various causes altered, so as to have their power diminished, increased, approached to or removed from the principal poles. The agents adequate to the production of these effects may be, heat and cold, volcanoes, earthquakes, electricity, chemical decompositions, and probably several others, of which philosophers have no knowledge.

With respect to the nature of that principle which causes magnetism, many hypotheses have been offered, but the most ingenious and consistent is that by Æpinus. This philosopher imagines that there exists a fluid which produces all the phenomena of magnetism, and which he consequently calls the *magnetic fluid;* he supposes the subtilty of this fluid to be so great, that it penetrates the pores of all bodies; and also, that it is of an elastic nature, viz. that its particles are repulsive of each other. At the same time he imagines that there is a mutual attraction between the magnetic fluid and iron, or other ferruginous bodies, but that all other substances have no action on this fluid; they neither attracting or repelling each other.

According to this hypothesis, iron and all ferruginous substances contain a quantity of magnetic fluid, which is equally dispersed through their substance, when those bodies are not magnetic; in which state they shew no attraction or repulsion towards each other, because the repulsion between the particles of the magnetic fluid is balanced by the attraction between the matter of those bodies and the said fluid, in which case those bodies are said to be in a natural state; but, when in a ferruginous body, the quantity of magnetic fluid belonging to it is driven to one end, then the body becomes magnetic, one extremity of it being now overcharged with magnetic fluid, and the other extremity undercharged. Bodies thus modified, or rendered magnetic, exert a repulsion between their overcharged extremities, in virtue of the repulsion between the particles of that excess of magnetic fluid, which is more than

overbalanced by the attraction of their matter. There is an attraction exerted between the overcharged extremity of one magnetic body and the undercharged extremity of the other, on account of the attraction between that fluid and the matter of the body; but to explain the repulsion which takes place between their undercharged extremities, we must, observes Cavallo, either imagine that the matter of ferruginous bodies, which, deprived of its magnetic fluid, must be repulsive of its own particles, or that the undercharged extremities appear to repel each other, only because either of them attracts the opposite overcharged extremities; both which suppositions are embarrassed with difficulties.

A ferruginous body, therefore, is rendered magnetic by having the equable diffusion of magnetic fluid throughout its substance disturbed, so as to have an overplus of it in one or more parts, and a deficiency of it in one or more other parts, and it remains magnetic as long as its impermeability prevents the restoration of the balance between the overcharged and undercharged parts. Moreover, the piece of iron is rendered magnetic by the vicinity of a magnet, because when the overcharged part or pole of the magnet is presented to it, the overplus of magnetic fluid in that pole repels the magnetic fluid away from the nearest extremity of the iron, which, therefore, becomes undercharged, or possessed of the contrary polarity, to the most remote part of the iron, which consequently becomes overcharged, or possessed of the same polarity as the presented pole of the magnet. When the piece of iron is rendered magnetic by presenting to it the undercharged extremity or pole of the magnet, then the part of the iron which is nearest to it, becomes overcharged, because that part of the magnet being deprived of its magnetic fluid, attracts the magnetic fluid of the iron to that extremity of the iron which lies nearest to itself. From this it appears, that in order to give magnetism to a body, as a piece of steel, the strength of the magnet employed must be such as to overcome the resistance which the substance of the steel makes against the free passage of the magnetic fluid, for which reason, a soft piece of steel is rendered magnetic more easily than a hard one; and a strong magnet will render magnetic such ferruginous bodies as a small one has no power upon.

When two equal magnets oppose their contrary poles to each other, they will, say the advocates of this hypothesis, preserve and strengthen their power; but when the two poles of the same name are placed near each other, then, if the strength and quality of these magnets be equal, they will only diminish each other's magnetic power; but if they be unequal in power

or quality, as in shape, hardness, &c. then the weakest will have its power diminished, destroyed, or changed, according as the superiority of the principal magnet is relatively greater or less.

By those who had so far deserted the paths of morality, as greedily to fatten upon the weaknesses of their fellow-creatures, and boldly to venture upon any practice, however really flagitious, if it promised gain, and was screened from legal punishment; a pretended art, called animal magnetism, was impudently announced as curative of all diseases incident to the human body. The vulgar, who are always perversely fond of a mysterious creed, seized the bait, and the pockets of the projectors overflowed with the receipts of imposition. When the folly of the moment had passed away, and the subject was rationally examined, abundant evidence was furnished, that though the human body contained, like most other substances, a small quantity of iron, the action of magnetism produced no physical change upon it, and that, therefore, the cures said to have been performed by magnetic sympathy, were either absolute falsehoods, or mere efforts of a deluded imagination. After animal magnetism appeared to have had its day, and was sinking fast into disrepute, it was succeeded by a kindred invention, the wonders of which were performed by rods of metal called *metallic tractors*: but these will quickly follow their parent to the grave, aud may be considered as already in the last stage of their existence.

Of Magnetical Instruments.

The Mariner's Compass.

The chief magnetical instrument, is the mariner's compass, which consists of a circular brass box, called the compass box, containing a card or paper divided into 32 points, at each of which is given the name of a particular wind, or name of the direction to which it points. Over the centre of this card is suspended an artificial magnet, which, from the smallness of its size, is called a needle. As the needle, allowing for its declination, always turns its north pole to the north, the helmsman can either keep the stem of the vessel always in the same direction, in which case he will sail due north, or he can keep the stem of his vessel in a direction any number of degrees distant from the north at his pleasure, by which means the compass becomes a universal guide. The needle, it must be noted,

is so placed, that its centre is exactly over some part of a line, running longitudinally through the middle of the keel. The compass-box is covered with a pane of glass, to prevent the wind from interfering with the motion of the needle.

It is necessary that the compass-box, whatever be the situation of the ship, should remain in a horizontal position. To secure this, it is suspended by what are called gimbals, in a square wooden box, which is fixed to the ship. These gimbals consist of two concentric rings, with axes at opposite points, as shewn at *a a*, *b b*, in the plan of the instrument, fig. 10, (pl. Aërostation—Magnetism.) The centres of the pivots of the gimbals should be in the same plane with the point of suspension of the needle.

The needle of the compass, when balanced before it is magnetized, will, after it is magnetized, be found to have lost its balance, on account of the dipping, which is greater or less, according to the latitude; for this reason, either the north end of the needle is made rather lighter than the other, or a small moveable piece of brass is fitted upon it, by shifting which nearer to or further from the centre, the needle may be balanced in all latitudes.

Compass needles are generally from four to six inches in length, with parallel sides, so that their section is a rectangle, except at the middle, which is swelled out in a circular form, to admit of being perforated, and yet to allow at least as much steel for the passage of the magnetic fluid, as if it had not been perforated. In the perforation is inserted, for the best compasses, a conical piece of agate, called a *cap*. This cap is hollow, and its apex rests upon the point of a steel pin standing up in the centre of the box. Thus mounted, the needle turns with extreme facility.

The card used by mariners, is divided, at the outer edge, into 360 equal parts or degrees, and within the circle of these divisions, it is again divided into the 32 equal parts or arcs abovementioned, which are called the *points of the compass*, or *rhumbs*, and each of which is often subdivided into quarters. The middle part of the compass is generally painted with a kind of star, the rays of which terminate in the points of the compass, or names of the winds. It may be interesting to many, to explain the principle upon which the points of the compass are named; as a knowledge of it will give more precise ideas of the direction meant when any of the names are mentioned. The four cardinal points of the compass, i. e. North, South, East, and West, form the terminations of two diameters standing at right angles: the four points ascertained by dividing the several quadrants, into two equal portions each, give com-

pound points, which are named after the two adjunct cardinals respectively; observing that North and South have precedence in each designation. Thus the middle point between North and East is called "North East," that between North and West is called "North West," and that between South and East is called "South East," and that between South and West is called "South West." By this means, eight equidistant points are obtained. In the next place, each segment between the several cardinals and their compounds, is subdivided into four equal portions; so that the whole circle is partitioned into thirty-two parts; that is, eight between each of the adjunct cardinals: the two points adjunct to North are "North by East," and "North by West;" those adjunct to South are "South by East," and "South by West;" those adjunct to East are "East by North," and "East by South;" while the adjuncts to West are "West by North," and "West by South." The two adjuncts to the compounds are as follows: to North East they are "North East by North," and "North East by East;" to South East they are "South East by South," and "South East by East;" to North West they are "North West by North," and "North West by West;" and to South West they are "South West by South," and "South West by West." There yet remain eight points, equidistant between the several cardinals and the compounds: these have their designations made by prefixing, to that of the adjunct compound, that of the cardinal to which it is nearest. Thus between North and North West, the point is called "North, North West;" and that between North West and West, is called "West, North West;" thus we have "North, North East," and "East, North East;" "South, South West," and "West, South West," "South, South East," and "East, South East." In the figure, the initials only of these designations are given, for want of room; but it may be observed at the same time, that the points of the compass are in general denoted only by their initials. The North point of the compass, is more commonly distinguished by a fleur-de-lis, or some other ornament, than by a letter.

In steering a vessel, it has been usual for the helmsman to have one compass, and the captain in his cabin to have another, and the want of a perfect correspondence between the instruments, or the inattention of one party, often rendered the helmsman chargeable with neglects, which he refused to acknowledge. To prevent these misunderstandings, and some other inconveniences, an improvement of the compass was thought of by Smith and Harris, Opticians, in Liverpool, and a patent taken out by them for the invention. They effected their purpose by making the card of thin paper rendered very

transparent, and placing it so that it could at once be used by the helmsman, and seen in the cabin. The advantages of the new compass have received that substantial acknowledgment which consists in the general use of the instrument and they are stated as follows:

1. The identical compass by which the helmsman is steering on deck, is plainly visible in the cabin.

2. The lamp or candle, which lights the binacle, is placed in the cabin, and cannot therefore be affected by the wind.

3. The binacle shews no light overboard, and the vessel cannot therefore be traced by an enemy at night.

4. The compass is so constructed, that the card cannot be displaced by any agitation of the vessel.

The Azimuth Compass.

This instrument is nearly the same as the preceding: the principal difference consists in the adaptation to it of two sights, through which the sun or a star may be seen, to find its azimuth, and thence to ascertain the declination of the needle at the place of observation. These sights are upright pieces of brass, placed diametrically opposite each other; in one of them is an oblong aperture, with a thread or slender wire stretched down the middle of it: the other sight contains only a narrow slit, of the same length, consequently the thread in the one sight is just opposite the slit in the other, and the observer knows when he looks through them centrally. The ring of the gimbals rests with its pivots on a semi-circle, the foot of which turns in a socket, so that without moving its outermost box, the compass may be turned round, in order to place the sights in the direction of the sun, star, or other object to be viewed; for this instrument is used to take the bearings of headlands, ships, and other objects at a distance, as well as for taking the declination of the needle.

The Dipping Needle.

To form this instrument, an axis is passed through a needle, of the same shape as the common needle; the terminations of the axis are conical, and they fit into small holes of the same shape in two cross bars, *f f*, fig. 11. The needle, before it is magnetized, must be made so as to lie perfectly horizontal, when suspended between these bars; then, after being rendered magnetic, its north pole will in this country be found to dip about 72 degrees below its former situation, or level of the horizon. In a lower latitude the dip will not be so great; in

a higher latitude it will be greater; and at the magnetic pole, which cannot be far removed from the pole of the earth, it would doubtless be vertical. The quantity of the dip is indicated by a graduated circle to which the needle points. This instrument, when used at sea, is suspended by a ring, that it may hang perpendicularly; but when used on shore it is set down on a stand EF, which has a spirit-level on it, and three screws to set it perfectly horizontal before the observation is made. It is of importance in using the instrument, to guard against the imperfection of the balance of the needle, which is perhaps best done, by reversing its magnetism, after an observation has been taken, and then taking another; the mean of the two observations may be assumed as the truth. The dipping needle must be placed in the magnetical meridian, to give a true indication.

Magnetical Experiments.

1. If a small magnet be placed upon a table, strewed with iron filings, and a tremulous motion be given to the table by a few blows, the filings will be observed to arrange themselves in a very curious manner. From the centre of each end or pole of the magnet, they will lie nearly in a straight line; but on each side of the magnet they will dispose themselves in concentric curves, both extremities of which terminate in the sides of the magnet, and they have pretty nearly the magnetic centre for their middle point. The cause of this appearance is, that each particle of iron becomes, for the moment, a magnet, and disposes itself accordingly, at the place where it lies, attracting, at the same time, the opposite poles of the neighbouring particles.

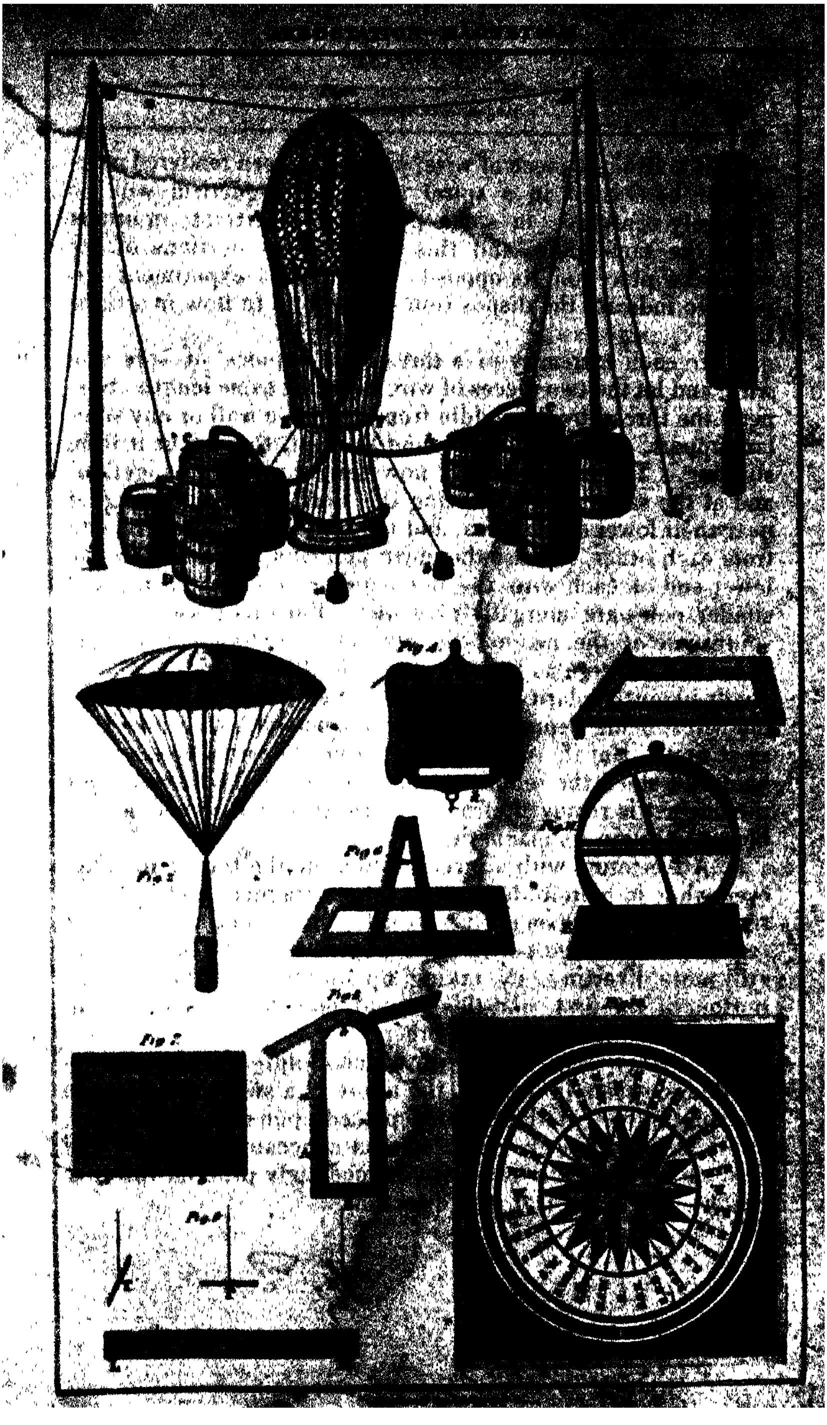
2. Select a piece of iron, the weight of which is rather more than a given magnet will support, in the ordinary manner of lifting it from a table or from the earth. Hold the iron upon the magnet, over another piece of iron, which should be at the distance of about an inch; thus circumstanced, it will be found that the magnet will support the iron which just before was too heavy for it. In this manner, a magnet will always lift a greater weight over a block of iron, than over any substance incapable of becoming magnetical. The reason is, that the detached piece of iron becomes for the time magnetical, the magnetism of its upper surface is the opposite of that of the pole nearest to it, and therefore, by increasing the power of the magnet, as opposite poles always do, it enables it to sustain a greater weight than usual.

3. If a straight piece of wire, which has been rendered magnetical, be twisted in a spiral form, its magnetism will be strangely confused: in some parts it will attract, in others repel the same pole, and this will in some portions of the wire take place on its opposite sides. This experiment appears to indicate the disposition of the fluid to flow in a right line.

4. To each extremity of a thread, tie a piece of soft iron wire, and let the two pieces of wire be of the same length. Suspend the thread by its middle from a nail in a wall or any similar support, folding it once round the nail, to prevent it from slipping. The two wires will now hang down close together, and at the same height. Bring the north pole of a magnet near their lower extremities, and they will immediately recede from each other, because the north pole of a magnet gives the lower end of each wire the opposite or south polarity, and similar poles are mutually repulsive. For this reason, if the south pole of the magnet be presented in like manner, the wires will diverge as before, although their lower ends have obtained north polarity. After the magnet has been withdrawn, the wires, being deprived of their magnetism, hang together as at first. But if, instead of soft iron, the wires be made of hardened steel, the repulsion once excited will continue after the magnet is removed, from the property of steel which enables it to retain its magnetism.

5. A tee-totum with a piece of iron in the top of it, may, even while in motion, be taken up by a magnet, and its motion, while thus suspended vertically, will continue as if it remained upon the table. The experiment may be rendered still more diverting, by taking up another tee-totum by the bottom of the first, and this second may have its motion in an opposite direction to the other.

6. Another experiment with which children are much delighted, consists in making the figure of a swan in wax, with an iron tongue; if this swan be placed upon a basin of water, and a piece of bread, with a magnet concealed in it, be held at some distance, the swan will immediately proceed towards it, and will follow it in any direction.



Abstract of Magnetism.

1. That principle which produces the phenomena of Magnetism, is not cognizable by our senses, except by its effects; but it is considered to be a fluid, and spoken of under the denomination of the *magnetic fluid*.

2. Iron has been usually considered as the only substance susceptible of magnetism; but late investigations, which have been made with great care, have rendered it extremely probable that both nickel and cobalt likewise submit to the influence of the same power.

3. Magnets are either *natural* or *artificial;* natural magnets are ores of iron, dug out of the earth in a magnetical state; artificial magnets are made of steel, by the help of a natural magnet, or of another artificial magnet.

4. In every magnet, there are two opposite points, which at all times and places, will, if the magnet be at liberty to move either without or with very little friction, turn to the poles of the world, or nearly so.

5. It is this singular property, which is called *polarity*, that renders the magnet so useful in navigation.

6. The poles of magnets, if of the same name, as when two north or two south poles are brought near together, *repel* each other; different poles, on the contrary, *attract* each other. The centre of a magnet neither attracts nor repels.

7. The earth itself acts as a great magnet, the poles of which nearly but not quite coincide with the geographical poles.

8. It is this difference between the magnetical and the geographical poles, that produces the declination of the needle, which turns to the former, and only indicates the latter by the nearness of the two.

9. The magnetical poles are not fixed points, but the cause of their motion is unknown.

10. The constant change which the motion of the magnetic poles produces in the *declination of the needle*, is the cause of what is called the *variation of the compass*.

11. At all places not 90 degrees from the magnetic poles, one pole of a magnet suspended by its centre sinks below the horizon, which is called the *dip* or *inclination* of the needle.

12. In the northern hemisphere, it is the north pole which dips; and in the southern hemisphere it is the south pole.

13. To render a natural magnet capable of lifting a weight with the force of both poles, it is furnished with an armature; an artificial magnet, for the same purpose, is made in the form of a horse-shoe.

14. Soft iron receives magnetism with great facility, but loses it almost immediately: steel, on the contrary, but especially hardened steel, is not easily affected; but the portion it receives, it permanently retains.

15. A magnet employed in the communication of magnetism, rather gains than loses strength.

16. A steel bar, rendered magnetic, and resting by its centre upon a point, so as to be at liberty to turn in any direction, is, with the box which contains it, and a card on which are written the names of the winds, called the *mariner's compass.*

17. The *azimuth compass* differs chiefly from the above in having two sights, through which may be seen the sun or any heavenly body, of which the azimuth is to be taken.

18. The dipping needle, is made by accurately suspending a bar of steel, in an unmagnetical state, on the pivots of an axis passing through its centre; it is then magnetized, and dips according to the action of the north or south pole upon it.

ELECTRICITY.

A DRY glass rod or tube, rubbed several times upwards and downwards with a dry hand, and immediately presented to light bodies of any description, will for a certain length of time alternately attract and repel them, if, after each repulsion, they have come in contact with some other body.—To that principle, which produces this effect, and to the science which treats of it in all its modifications, is given the name of *electricity*. The term electricity is derived from the Greek word signifying amber, and has been adopted because amber was the first substance upon which friction was known to produce this effect.

History of Electricity.

The earliest account of electricity, artificially excited, of which we have any record, is carried as far back as 600 years before the birth of Christ, when Thales, the Milesian, observed that amber, after having been rubbed, possessed the power of attracting light bodies, such as feathers, &c. We have no proof that much notice was taken of this fact; indeed it would appear of too little consequence to be much regarded; and it does not even seem to have been known that any other substance resembled amber in its attractive property after friction, till about 300 years afterwards, when Theophrastus mentions that a stone, which he called *lyncunium*, and which is supposed to be the same with what is now called the *tourmalin*, possessed the same peculiarity. From this period commences another chasm in the history of electricity, of 1900 years' duration. The commencement of the seventeenth century, may be considered the earliest era at which the science takes its date. The person who first contributed essentially to its establishment, was Dr. William Gilbert, who, in the year 1600, published a book *De Magnete*, which contains a variety of electrical experiments, relative, however, merely to such substances as had the properties of amber, the whole of which class of bodies are now called electrics. These properties as yet excited no general interest; they became not the exclusive object of any one's attention, but only transiently arrested the notice of those whose researches extended to every branch of knowledge, however unpromising and trivial its appearance. After the date of Gilbert's book, additions continued to be

made to the catalogue of electrics, but nothing of moment was observed further, till about the year 1670. About this time, the celebrated Robert Boyle greatly enlarged the catalogue of electrics, discovered that their effects were increased by wiping and warming them before they were rubbed ; and saw a faint elicitation of the electric light, from some diamonds which he had rubbed to give them the power of attraction.

Otto Guericke, of Magdeburg, who was contemporary with Boyle, and justly famed as the inventor of the air-pump, was eminently successful in his electrical pursuits. He constructed a globe of sulphur, to which he applied his hand, while it was whirled round in a proper frame, by which means he had the pleasure of observing that he obtained an accumulation of electricity far beyond any former example, and which enabled him to perform a great variety of electrical experiments with singular advantage. He discovered electrical repulsion, and not only saw in a state of intensity the electric light, of which Boyle had seen but a glimpse, but heard the sound with which it is accompanied. He also observed that a feather, when repelled by an excited electric, always keeps the same side towards the body which repels it, and that, after having been repelled, it is not again attracted till it has touched some other body.

The torch of investigation into this subject, had now become distinctly lighted, and the number of discoveries increasing with considerable rapidity, kept alive curiosity, though not without some fluctuations. Dr. Wall, by rubbing amber upon a woollen substance in the dark, produced considerable quantities of electrical light, accompanied by a crackling noise ; and he remarked, that "this light and crackling seems, in some degree, to represent thunder and lightning." In 1709, appeared a treatise by Hauksbee, which possessed great merit. The author repeated and confirmed the experiments of Dr. Wall, and noticed the sensation communicated to the hand by the electric spark. He introduced the important improvement of using a glass globe instead of a sulphur one, and among other new experiments, relates a method of rendering opaque bodies transparent by means of electricity. He lined more than half of the inside of a glass globe with sealing-wax ; and having exhausted the globe, he put it in motion ; when, applying his hand to excite it, he saw the shape and figure of all the parts of his hand distinctly and perfectly, on the concave superficies of the wax within, just as if only uncoated, pure glass had been interposed between his eye and his hand. The lining, where it was spread the thinnest, would but just allow the sight of a candle through it in the dark ; but in some places

the wax was at least the eighth part of an inch thick; yet the whole appeared equally transparent. The wax did not adhere to the glass in all places, but this seemed an immaterial circumstance.—Pitch answered the purpose as well as sealing-wax.

Sir Isaac Newton's discoveries attracted so much notice, that electricity was kept for a time in the back ground; but soon after the decease of that great man, the opening that appeared for new discoveries in it again brought it forward. Hitherto the distinction between electrics, such as amber, glass, &c. which were excited by rubbing, and those bodies which were only capable of receiving electricity, appears to have been scarcely thought of. The distinct view of it was accidentally obtained by Stephen Grey, in the year 1729. After many ineffectual attempts to excite an electric power in metals, by heating, rubbing, and hammering, he recurred to a suspicion he had for some time entertained, that, as a glass tube, when rubbed in the dark, communicated its light to various bodies, it might possibly at the same time communicate to them an electricity or power of attracting light bodies. To examine this matter, he provided himself with a glass tube, three feet five inches long, and nearly one inch and two-tenths in diameter. To each end was fitted a cork, to keep the dust out when the tube was not in use. His first experiments were made with a view to determine whether the tube would attract equally well with the ends closed by corks, as when they were open. In this respect there was no difference but he found that the corks attracted and repelled light substances even with rather more power than the tube itself. He then fixed an ivory ball upon a stick of fir, about four inches long, and thrusting the end of the stick into one of the corks, he found that the ball obtained a strong power of attraction and repulsion. He varied the experiment, by fixing the ball upon long sticks, and upon pieces of brass and iron wire, and always obtained the same result; also when he suspended the ball by a packthread from a balcony twenty-six feet high, he still found, at this and all other heights, that by rubbing the tube, the ball acquired the same power as in his first experiment.

Grey's next attempt was to ascertain whether electricity could be conveyed horizontally as well as perpendicularly. With this view he fixed a cord to a nail which was in one of the beams of the ceiling, and making a loop at that end which hung down, he inserted his packthread, with the ball at the end of it, through the loop of the cord, and retired with the tube to the other end of the room; but in this state he found that his ball had no power of attraction. Wheeler, a friend of his, to

whom he related his disappointment, suggested that the supporting packthread, from its coarseness, might intercept the electric power, and proposed to substitute a silken thread. Upon this change being make in the apparatus, the experiments (which were made by Grey and his friend jointly) completely succeeded, and the ivory ball shewed signs of electricity at the distance of 147 feet from the glass tube. In subsequent experiments, they increased the conducting cord, till at length the silken thread supporting it, broke: as they attributed their success, since the adoption of the silken thread, entirely to the fineness of that material, they naturally conjectured that brass or iron wire would be still more advantageous; upon making the trial, however, they were completely disappointed, for they found that the ivory ball betrayed not the slightest evidence of electricity. They therefore again resorted to the use of silk, but used it thicker than before; and by this means conveyed the electric power, without any apparent diminution, to the distance of 765 feet.

Such were the experiments which immediately led to the important truth, that though a great number of bodies had the power of conducting the electric energy, yet there were other bodies which entirely stopped its course; and as the former were called *conductors*, the latter were called *non-conductors*. It was soon found that those bodies which shewed signs of electricity by rubbing were always non-conductors, and that those which could not be brought to this state, were conductors. Grey continued a zealous electrician to the time of his decease, and made many interesting discoveries. In particular, along with his friend, he discovered the method of insulating bodies which were electrified, by placing them upon a non-conducting body, and thus preventing the electricity they have received from immediately flying off.

The capital discovery made by Grey and Wheeler, had been announced but a short time, before another, scarcely less important, was made by Du Fay, who was intendant of the French king's gardens. It arose from casually observing, that though an excited glass tube repelled a piece of leaf gold, yet an excited piece of gum copal eagerly attracted the same material. Du Fay found upon trial, that sealing-wax, sulphur, resin, and a number of other substances, produced the same effect as gum copal. To the electricity of those substances which attracted the gold leaf after excitation, he gave the name of the *resinous* electricity, as they were most of them resins; and to the electricity of glass he gave the name of the *vitreous* electricity, for he entertained not a doubt but their name was

as opposite as their effects. Du Fay, among other experiments, found it impossible to excite a tube in which the air was condensed; and in repeating Grey's experiments, with a pack-thread, he perceived that they succeeded better by wetting the line. Hair being a non-conductor, Grey had insulated and electrified a boy by suspending him with hair lines;* Du Fay, in repeating this experiment of the effects of electricity on the animal body, suspended himself by silken cords; in this situation, sparks of fire were drawn from him, on his being touched by any one, and both he and the other person felt a sharp pain at the instant of contact, which was accompanied by a snapping noise. When another person, by holding a rod of metal, touched the one that was electrified, the spark was drawn as before. From this instance of the accumulation of electricity, and its being drawn off by metal, Grey inferred, and in fact, his former experiments in electrifying insulated substances had proved, that electricity might be collected in metal, as well as the animal body, and drawn off, during a short interval, as it was wanted. This suggested to him the propriety of that part of an electrical machine now called the prime conductor, which he formed by suspending a piece of metal near his excited glass tube, and thus was enabled to draw sparks from it. The method of making the prime conductor in the form of a tube was first adopted in Germany, in 1742, where the use of the glass globe adopted by Hauksbee was revived, and the conductor was at first supported by a man standing upon cakes of resin, but afterwards it was suspended by silken lines. In Germany, also, about the same time, a woollen rubber was used instead of the hand to excite the globe.

Electricity had now become decidedly a part of philosophy, and it had become the duty of some to study that they might teach it; whilst others, who were disposed to the acquisition of knowledge, were incited by the desire of proving what others had asserted, or the higher motive of finding out something new. In this conflict of exertion, a discovery was made that may justly be considered as forming an epoch in the history of the science, which it immediately raised to an extraordinary degree of estimation. This discovery consisted in the art of accumulating electricity, by what is now called the *Leyden phial.* Towards the close of the year 1745, Von Kleist, dean of the cathedral of Camnin, made an experiment, of which he sent the following curious account to Dr. Leiberkulm, at Berlin: "When a nail, or a piece of thick brass wire, &c. is put into a small apothecary's phial, and electrified, remarkable effects follow: but the phial must be very dry or warm. I

commonly rub it over beforehand with a finger, on which I put some pounded chalk. If a little mercury, or a few drops of spirit of wine, are put into it, the experiment succeeds the better. As soon as this phial and nail are removed from the electrifying glass, or the prime conductor to which it hath been exposed, is taken away, it throws out a pencil of flame so long, that with this burning machine in my hand, I have taken above sixty steps in walking about my room. When it is electrified strongly, I can take it into another room, and there fire spirits of wine with it. If, while it is electrifying, I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders. A tin tube, or a man placed upon electrics, is electrified much stronger by this means than in the common way. When I present this phial and nail to a tin tube, which I have fifteen feet long, nothing but experience can make a person believe how strongly it is electrified. Two thin glasses have been broken by the shock of it." In this experiment, as the phial was of small dimensions, and as the circumstances essential to its greatest effects were not combined, because they were unknown, the power of the electricity accumulated was inconsiderable; but soon afterwards, the art of giving a strong shock was discovered in Holland, because the vessels employed happened to be larger. As it was known that the air, or the particles floating in it, abstracted the power of electrified bodies, so that even insulation was no remedy against their being in a short time deprived of it, an idea suggested itself to Muschenbroek and some of his friends, that if the electrified body were entirely surrounded by a non-conductor, the dissipation of the electricity would in a great measure be prevented. To realize this idea, a quantity of water was put into a bottle, and electrified till it was thought to be fully charged; but here the original intention of the experiment was lost sight of, by an unexpected result which swallowed up all their attention. Cunæus, happening to hold his vessel in one hand, while he endeavoured to disengage it from the conductor with the other, suddenly received a shock, which shook many of his joints, passed through his breast, and in a high degree stunned and terrified him. In this manner was discovered what still continues to be called the *electric shock*. At this day it excites a smile to observe the terms in which the shock is spoken of by several of those who first submitted to its effects. Muschenbroek, who tried the experiment with a thin glass bowl, told his friend Reaumur, in a letter written shortly afterwards, that he felt himself struck in his arms, shoulder, and breast; that he lost his breath for a time, and did not feel

himself well again for the space of two days. He adds, that he would not take a second shock for the whole kingdom of France. In terms almost equally heightened by terror, speaks Allamand; though he only made the experiment with a common beer-glass, he declares that he lost his breath for some moments, and felt such an intense pain in his right arm, that he was apprehensive of bad consequences. Other philosophers were, however, found, who had the resolution to take several shocks of great intensity; and one of the most hardy wished that he might die by the electric shock, in order that his death might furnish an article for the memoirs of the Parisian Academy.

After the art of giving a shock by means of a phial or jar had been discovered, the art of combining several jars, so as to unite their powers in one discharge, soon followed, and this improvement constituted what is now called a *battery*. It was made by Dr. Franklin, and resulted from his reflections on the phenomena of the Leyden phial. It had been found, that by coating the outside of the phial with a conducting substance, which communicated by a wire with the person who discharged it, the strength of the shock was exceedingly increased; and that unless some conducting substance was in contact with the outside of the jar, no charge could be given. Dr. Franklin, in accounting for this circumstance, suggested that a charged phial or jar contained no more electricity than before; that as much was taken from one side as the other had above its natural portion, and that to discharge it, nothing more was necessary than to make a communication between the two sides; the electricity being by this means enabled to regain its equilibrium, that equilibrium was instantly restored, and no signs of electricity remained. He also demonstrated by experiments, that the electricity did not reside in the coating, as had been supposed, but in or upon the glass itself. After a phial was charged, he removed the coating, and found that upon applying a new coating, the shock might be received. When, to any body or surface, was attributed the property, according to this theory, of having more than its usual portion of electricity, the Doctor proposed to distinguish its state by the term *plus* or *positive*; when the body or surface had less than its usual share of electricity, its state was distinguished by the term *minus* or *negative*. These terms answered the same end, and expressed the same things, as those of vitreous and resinous, proposed by Du Fay, but they were supposed to be so much more appropriate, that their admission into the language of the science soon became complete. It may only therefore be necessary in this place to remark further, that bodies

electrified plus or positively, are those possessed of the vitreous electricity of Du Fay; while those electrified minus or negatively, are possessed of what he termed the resinous electricity. The former seek every opportunity of imparting, and the other of receiving, electricity. This consideration of the subject induced the supposition, that if the insides of several jars were connected by means of a conducting substance, and their outsides connected with each other in like manner, they would receive and impart a charge like a single jar, with the difference only of power, which would be increased in proportion to their number and size; and thus a battery of any force would be obtained. By a battery it was found that small animals might be instantly killed, as if struck by lightning; and these convincing examples of its power, induced philosophers, where life was concerned, to be more cautious in the use of it than they had been with the jar; but experiments of other kinds were prodigiously multiplied. It was proved that the electric matter might be conveyed to distances much exceeding what had yet been conjectured; the French philosophers conveyed it nearly three miles, and Dr. Watson (the late bishop of Llandaff) conveyed it four miles, a distance which it traversed instantaneously. In another experiment made by Dr. Watson, the electric matter was conveyed by a wire through the river Thames, and spirits were kindled by it, after it had run through this watery circuit. In other experiments it has been conveyed nine miles, and a shock has been sent through 1800 men, with a velocity immeasurably rapid.

The field for electrical experiments had now become very extensive, but there still wanted data that might lead to a more minute knowledge of the nature of the principle thus brought into action, and of the various circumstances that were essential to its production. Dr. Watson, however, made some experiments which tended to these points. Having rubbed a glass tube, while he was insulated, by standing upon a cake of wax, in order to be electrified, he found that no snapping could be drawn from him by another person who touched any part of his body; but if a person not electrified held his hand near the tube while it was rubbed, the snapping was very sensible. He also observed that if an electrical machine, and the person who turned it, were suspended by silk, no fire was produced; but if he touched the floor with one foot, the fire appeared upon the conductor. From these and other experiments of a similar nature, he inferred, that glass tubes and globes only afford the means of obtaining the electric energy, which does not reside in them, but is derived by them from some external source

Dr. Franklin's explanation of the phenomena of the Leyden jar, and of plus and minus electricity, was given in the course of a correspondence with his friend Collinson, in England, to whom he also communicated a curious and important observation on the power of points in drawing and throwing off the electric matter. The first intimation of the latter particular, he derived from one Thomas Hopkinson, who electrified an iron ball of three or four inches in diameter with a needle fastened to it, expecting to draw a stronger spark from the point of it; but his expectation was entirely frustrated.

The attention of those inclined to philosophical pursuits in Philadelphia, had been directed towards electricity by the care of Collinson, who, about the year 1745, had sent to the Library Company in that city, an account of the extraordinary experiments then performing in Europe, together with a tube, and directions for its use. But Dr. Franklin's eagerness in the research, and his success in making discoveries, exceeded that of all his friends. In the year 1749, he suggested an explanation of the phenomena of thunder-gusts, and of the aurora borealis, on electrical principles; he pointed out many particulars in which lightning and electricity agree; and in adverting to the power of pointed rods in drawing off lightning, he supposed that pointed rods of iron fixed in the air, when the atmosphere was loaded with lightning, might, without noise or danger, draw from it the matter of the thunder bolt into the body of the earth. His words are: "The electric fluid is attracted by points. We do not know whether this property be in lightning: but since they agree in all the particulars in which we can already compare them, it is not improbable that they agree likewise in this; let the experiment be made." The earliest observation, it will be recollected, on the similarity of electricity and lightning, was made by Dr. Wall. On the supposition of the identity of lightning and electricity, Franklin immediately saw and pointed out, that houses and ships might be secured from the effects of lightning by pointed iron rods, which should rise some feet above the most elevated part of them, and descend some feet into the ground or the water.

The manner in which Dr. Franklin proposed to bring his speculations to trial, was to erect, on the top of a tower, or other elevated place, a sentry-box, from which might rise a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this, would, he conceived, impart to it a portion of their electricity, which would be rendered evident by the sparks it yielded on being touched by any con-

ductor. Philadelphia at this time contained no building which Franklin deemed proper for his purpose; he therefore laid aside the thoughts of realizing his conjecture, till the erection of some convenient edifice furnished him with the situation he required. But while he thus postponed the completion of his views, they were, by the following means, realized in France, and produced incredible surprise.

Franklin had communicated to his friend Collinson, regular accounts of his proceedings and theories, and Collinson published them for the information of the world. They were soon extensively circulated, and translated into different languages. In France, the principles of Franklin, and several of the experiments by which they were supported, soon became familiar to some of the chief philosophers, and several of them, among whom were D'Alibard, and De Lor, determined separately to undertake the experiment Franklin had proposed for bringing lightning from the clouds. D'Alibard prepared his apparatus at Mary-la-ville, about five or six leagues from Paris: it consisted of an iron rod forty feet long, the lower extremity of which was brought into a sentry-box, where the rain could not come; while on the outside it was fastened to three wooden posts by long silken strings defended from the rain. In his absence, he entrusted the care of the machine to a joiner named Coissier, a man of sense and courage, whom he furnished with directions how to proceed in case of a thunder-storm. On the 10th of May, 1752, between two and three in the afternoon, Coissier heard a clap of thunder. He ran to the apparatus, for D'Alibard was then absent, and drew sparks from the rod, in the presence of several witnesses. Eight days afterwards, De Lor proved equally successful with his apparatus.

While the laurels with which posterity should crown the memory of Franklin were thus springing up in Europe, where his character now became emblazoned with a general admiration of which he was ignorant, he had himself devised the means of easy access to the elevated regions of air. He concluded that a pointed rod of a moderate height would not answer, and therefore did not try one; but it occurred to him that a common kite, such as children amuse themselves with, would reach any height he wished. He accordingly prepared one of silk, that it might not be injured by rain, the straight piece of wood up the middle of it was pointed with iron, and at the first approaching thunder-storm, he went to a convenient situation for raising it. He was assisted by his son, to whom alone he communicated his intentions, possibly with a view to avoid the

appearance of premature boasting if he should be unsuccessful, and not uninfluenced by a wish to avoid the ridicule which would in that case attach to him. The string of the kite was of hemp, as usual, except at the lower end, which was of silk. Where the hemp terminated, was fastened a key. After the kite had been raised, a thunder cloud passed over it; but no electricity appeared. Disappointment appeared to be impending; when suddenly some loose fibres of the hempen string appeared to stand erect and to avoid one another, as if they had been suspended by the conductor of a common electrical machine; he presented his knuckle to the key, a strong spark ensued, and as soon as the string became wet, the supply of electricity became copious. He afterwards prepared an insulated iron rod, to draw the lightning into his house, and by means of real lightning, he performed all the experiments usually executed by means of electrical machines. This memorable experiment was tried in June, 1752: the French philosophers had therefore the precedence in point of time; but they had only trod in the path which Franklin had explicitly pointed out to them.

When the method of giving the electric shock had just been discovered, such was the influence of the feelings it inspired, that many of those who received it appeared to think no terms too extravagant to convey an idea of the violent effects of a charge which may be borne by a child; but now the time for real terror had arrived; and many who incautiously adventured to bring down the ethereal fire, suffered much by violent shocks, while they incurred the most imminent hazard. In one instance, a fatal catastrophe ensued, and we shall record it for the sake of strongly impressing upon the young electrician the necessity of caution: On the 6th of August, 1753, Professor Richman, of Petersburg, was making experiments on lightning drawn into his own room. He had provided himself with an instrument for measuring the quantity of electricity communicated to his apparatus, and as he stood with his head inclined to it, Solokow, an engraver, who was near him, observed a globe of blue fire, as large as his fist, jump from the instrument, which was about a foot distant, towards his head. The professor was instantly dead, and Solokow was also much hurt. The latter could give no particular account of the way in which he was affected, for, at the time the professor was struck, he stated that there arose a sort of steam or vapour which entirely benumbed him, and made him sink down to the ground, so that he could not even remember to have heard the clap of thunder, which was very loud. The globe of fire was attended with an

explosion like that of a pistol; the instrument for measuring the electricity was broken to pieces, and the fragments thrown about the room. Among other effects of the lightning in the chamber, the door-case was found to be half split through, and the door torn off and thrown into the room. A vein was opened in the professor's body twice, but no blood followed: after which attempts were made to recover life by violent friction, but in vain: upon turning the corpse with the face downwards, a small quantity of blood ran out at the mouth. There appeared a red spot on the forehead, from which came some drops of blood through the pores, without wounding the skin. The shoe belonging to the left foot was burst open, and on uncovering the foot, at that part was found a blue mark, whence it was inferred that the electric matter, having entered at the head, made its way out again at that foot. Upon the body, particularly on the left side, were several red and blue spots, resembling leather shrunk by heat, and many more became visible over the whole body, particularly over the back. That upon the forehead changed to a brownish red, but the hair of the head was not singed. In the place where the shoe was unripped, the stocking was entire; the coat also was wholly uninjured, and the waistcoat was only injured on the fore-flap where it joined the hinder. On the back of Solokow's coat appeared long narrow streaks, as if red-hot wires had burnt off the nap.

When the professor's body was opened the next day, the cranium was very entire, having neither fissure nor contra-fissure: the brain was sound, but the transparent pellicles of the wind-pipe were excessively tender. There was some extravasated blood in it, as also in the cavities below the lungs. Those of the breast were quite sound; but those towards the back of a brownish colour, and filled with more of the blood above-mentioned. The throat, the glands, and the small intestines, were all inflamed. The leather-coloured spots penetrated the skin only. In forty-eight hours, the body was so much corrupted that the removal of it had become difficult.

Explanatory Remarks.

A general idea of a science may often be communicated more perfectly by a review of the rise and progress of that science than by any other means. This remark applies to electricity with greater force than to many other branches of knowledge; and in drawing up the preceding historical sketch, attention has been paid to the extrusion of matter which had

not instruction for its object. Among other points, the chief technical terms belonging to the subject have been in a good degree explained; but to render the reference to them easy, we shall here collect and explain them more fully.

All bodies which admit electricity to pass through them, are called *conductors of electricity*; the same bodies are often called *non-electrics*.

All bodies which are impermeable to electricity, are called *non-conductors of electricity*; they are also called *electrics*, with almost equal frequency.

The following lists of these bodies will be useful to the reader: they are classed according to their excellence:

Conductors or Non-electrics.

Gold,
Silver,
Copper,
Platina,
Brass,
Iron,
Tin,
Quicksilver,
Lead,
Semi-metals, and metallic ores,
Black lead, or carburet of iron,
Charcoal from all substances,
The fluids of an animal body,
Salt-water, fresh-water, and all non-elastic fluids, except fixed oils.

Ice and snow, till cooled down—13° of Fahrenheit's thermometer; below this temperature, Achard, of Berlin, found that they became electrics.

Most saline substances, of which the metallic salts are the best.

Earthy substances,
Smoke,
The vapour of hot water.

Electrics or Non-conductors.

Glass, and vitrifications, whether of earths or metals,
All precious stones, of which the most transparent are the best,
Amber,
Jet.

Sulphur,
All resinous substances,
Baked wood,
Wax,
Silk,
Cotton,
Silk, hair, wool, feathers, and most animal substances, when dry,
Paper,
Air, and other elastic fluids,
Fixed oils,
Metallic oxides,
The ashes of animal and vegetable substances,
Dry vegetable substances,
Most hard stones, of which the hardest are the best.

The substances enumerated in each of these classes, do not, under all circumstances, preserve their distinctive character. Thus glass, the best electric, becomes a conductor when red-hot; and rosin, another excellent electric, becomes a conductor when melted. The air also becomes a conductor when damp, and at ordinary temperatures is never so free from moisture as not to carry off electricity in some degree. In short, no substance is known to be perfect according to its class: the best conductor offers some resistance to the passage of the electric fluid; and over or through the best electric this subtile agent is in some degree transmitted. It occasionally happens that the same substance becomes changed in its electrical properties without any assignable cause: parcels of glass are sometimes met with which are imperfect conductors, yet in the course of time they change to good electrics; or on the contrary, if good electrics at first, they change to imperfect conductors. The properties of any particular piece of charcoal can hardly be known without examination: some pieces of it are good conductors, others quite the reverse. Baked wood only remains a good electric, while it continues free from moisture; green vegetables, fresh wood, &c. are conductors on account of the water they contain. Hence when electrics are to be excited, it is necessary to guard against the effects of moisture, by warming them; and baked wood is varnished, and afterwards thoroughly dried, on the same account.

It is a disputed point whether a perfect vacuum is a conductor or not. The vacuum of the best air-pump, for example, when the air is rarefied one thousand times, is pervaded by electricity; but according to Walsh and Morgan, the best Torricellian vacuum is a non-conductor; other experiments,

however, of which several were tried by Walker, with every precaution, evince the contrary.

Bodies which are supported by electrics, so that their communication with the earth, by means of any conductor, is interrupted, are said to be *insulated:* thus a person is equally insulated when he stands upon a stool with glass legs, or is suspended by silken cords from a ceiling.

When an electric, by rubbing it with another body, or by any other means than that of direct communication with another electrified body, is brought into an electrified state, that is, a state in which it alternately attracts and repels light bodies, it is said to be *excited.* Electrics are the only bodies susceptible of excitation, and it is by this property they are distinguished from conductors.

The hand, a piece of leather, or any other body by which an electric is rubbed, with a view to its excitation, is called a *rubber.*

Electricity is found to be of two kinds, which are generally distinguished by the appellations of *positive* and *negative,* or their equivalents *plus* and *minus.* In what the difference of these electricities consists, has been much contested. Dr. Franklin, we have observed, argues that when bodies are electrified positively, their electricity is redundant, or greater than their natural quantity; when they are electrified negatively, on the contrary, he supposes that part of their natural quantity of electricity is abstracted The consideration of this subject will be resumed hereafter, but it may be observed in this place, that the positive and negative electricities attract each other; though each kind strongly repels itself when existing in two different bodies. We have also observed before, that the positive electricity has been called the *vitreous,* and the negative the *resinous;* but these two terms are little used.

The two electricities may be distinguished in the following manner: if a pointed conductor, such as a needle, be presented to an excited glass tube in the dark, a globular speck of light will be observed upon its point, which is a proof that the tube is electrified positively: but if this pointed conductor be presented to an excited stick of sealing-wax, a stream or pencil of light will be observed, which is an equally distinctive mark of the negative electricity in the electric.

The same substance, excited by a different rubber, will alternately be electrified plus and minus. If a polished tube or piece of glass be drawn across the back of a cat, it acquires the negative electricity; with a rubber of any other substance, it acquires the positive electricity. If the glass be roughened,

it acquires the negative electricity, when the rubber is the human hand, woollen cloth, wax, &c. but the contrary when dry oiled silk, sulphur, or metals, are the rubbers. When the roughened glass is greased, and rubbed with a rough surface, it resumes the positive electricity. It seems a general rule, that the smoothest of two bodies will, on friction, exhibit positive electricity. White silk becomes positive when black silk is the rubber; and negative when paper or the hand is the rubber. Sealing-wax is positive when rubbed with metals, and negative when rubbed with the hand, leather, woollen cloth, &c.

A rubber acquires the electricity opposite to that of the body it is employed to excite; for the two electricities always accompany each other.

The cause of electricity is supposed to be a fluid, which is therefore called the *electric fluid*.

Any electric body, the surfaces of which possess the two different electricities, is said to be *charged*.

Our object will now be to describe the construction and use of the principal machines by which electricity may be accumulated, and accommodated to the purpose of experiment: the details of a variety of experiments will then follow, and after having thus brought forward some of the most interesting facts of the science, we shall proceed to the consideration of the theory of electricity.

Of Experimental Apparatus.

The Cylinder Machine.

The simplest kinds of electrical apparatus, such as glass tubes, rolls of sealing-wax, cakes of resin, &c. require no separate description, as they will be sufficiently understood by their names. We shall therefore commence with the description of the cylinder machine, which is most commonly designated by the appellation of "the electrical machine," without any further mark of distinction.

The cylinder machine is represented by fig. 1, pl. I. The various parts of which it consists, are supported upon a stout board, AB, which is generally made of mahogany for the sake of neatness. In the two pillars or supports CD, turn the pivots attached to the hollow glass cylinder E. This cylinder should be well annealed, made as true as possible, and be perfectly clean and dry within. In the centre of each end it

has a short neck, upon which are cemented caps, either of wood or brass. These caps have pivots upon them, of which the one that enters the pillar D simply works in that pillar; but the other passes entirely through the pillar C, and the winch F, by which the cylinder may be revolved, is fastened upon its extremity. The part of the winch *a b*, is sometimes made of glass, in order the more effectually to prevent the escape of the electric fluid collected on the cylinder. The glass is adapted by having a brass or wooden cap cemented on each end of it; to one of these caps is fitted the part F, held in the hand; and in the other is a square hole, to be received upon the square termination of the pivot of the cylinder, and there fastened by means of a screw.

The pillars, CD, if made of wood, must be completely dried, by baking in an oven, and afterwards varnished: but they are often made of solid glass cylinders, cemented at the top and bottom into metal or wooden caps, as mentioned for the handle, and also exemplified in the manner of supporting the conductor and rubber mentioned below.

G is the rubber, which consists of a cushion stuffed evenly with curled hair, a little concave on the face, that it may apply itself flat against the cylinder. The back or outside of the cushion is made of wood, rounded on all its edges. The side next the cylinder is covered with leather, generally red bazil. To the lower edge of the cushion is glued a piece of black silk, of equal breadth; this flap is brought up between the cushion and the cylinder, and lies over about one half of the latter. The silk generally used is that called black mode. The support *g*, of the rubber, is a pillar of glass cemented into a socket or cap of metal at the top and bottom, for the convenience of affixing the other parts: at the bottom it is fixed in a sliding piece, to admit of its being set so as to press with more or less force against the cylinder. When it is set in the manner required, a small screw, *h*, prevents the sliding-piece from yielding. The cushion also has another adjustment. The cylinder, with whatever care it may be fastened upon its pivots, will not revolve with the precision of a body formed in a lathe, because, being only blown glass, it is not true itself; hence to render the pressure against it tolerably uniform, a spring is placed within the cushion, in the manner shewn by fig. 2, where the spring *x x*, is seen edgeway. This spring spreads itself out, when the pressure is increased by a swell of the glass; and on the contrary, when the pressure is diminished by a hollow, the spring becomes more incurvated. The size of the spring is equal to that of the cushion, and it is fastened by a pin in the middle to the board *y*, to keep it in its place.

The prime conductor, H, is supported in the same manner as the rubber, but does not slide at the bottom. It consists of a tube of brass or tin-plate, or any other conducting substance: for large machines it is often made of pasteboard. Its terminations are generally globular, but the chief rule to be observed in forming it is to make it free from all sharp edges or corners, which would rapidly throw off the electric fluid. Hence even when holes are made in the prime conductor, they should be well rounded at the edges. The prime conductor may either be placed at right angles to or parallel with the axis of the cylinder. When placed in the former position, the globular end of it at the greatest distance from the cylinder is often made larger than the other, because there the electricity makes the greatest effort to escape. At that end of the prime conductor which is next the glass, are fixed two or three short, pointed wires, which draw off the electricity rapidly from the cylinder, and are called *collectors*.

The size of the conductor is of some importance as well as its form. The larger it is, the denser and longer the spark which may be drawn from it; regard must, however, be paid to the size of the cylinder, otherwise the dissipation from the surface of the conductor may destroy the advantage of its size.

A wire *k*, with a globular head, is often fixed at the end of the prime conductor, into which it is screwed, in order to be removeable at pleasure. From the knob of this wire may be drawn a longer spark than from any other part of the machine.

The rubber, used in the state it has been described, will produce only an insignificant excitation of the cylinder; in order therefore to increase its effect, it is rubbed with a mixture of metals called an amalgam. Amalgams are differently prepared, but the best are made of tin and mercury, or zinc and mercury. Cavallo directs the amalgam of tin to be made by mixing two parts of mercury with one of tin-foil, adding a little powdered chalk, and mixing the whole until it becomes a mass like paste. For the amalgam of zinc, heat four or five parts of mercury higher than the boiling point of water, and have in readiness one part of melted zinc. Pour the heated mercury into a wooden box, and immediately after pour the melted zinc upon it. Close the box, and shake it for about half a minute. After the amalgam thus made is cold, mix it by trituration with a small quantity of grease, such as tallow, mutton, suet, &c. a very small quantity of finely powdered whitening, and about a fourth part of the above amalgam of tin. This amalgam of zinc is the best.

Before the amalgam is applied, the cylinder and flap should be freed from all kinds of dirt or dust; a leather covered with tallow may then be held against the cylinder while it is turned. When the glass is entirely obscured, lay the greased leather aside, but continue to turn the cylinder till the flap has taken off part of the grease; then if a small quantity of the amalgam, spread upon another piece of leather, be held against the under side of the cylinder while it is revolved, the excitation will soon become very strong, and sparks may be obtained in abundance.

Many experiments have been made to ascertain the best mode of constructing the rubber, and the one described has been found the best: the principal point to be observed is, to make the side that touches the glass as perfect a conductor as possible, in order to supply electricity, which is accomplished by the use of the amalgam, while the back of the rubber should be one of the best non-conductors, in order that it may not take back again the electricity excited on the glass.

The cement by which the caps of the cylinders are fastened to their necks, and the insulating glass pillars of the rubber and prime conductor to their sockets, is made by melting equal quantities of bees-wax and rosin with one-fourth of their weight of red ochre.

When baked wood is employed for the insulating supports of the cylinder, rubber, and prime conductor, it must, as already observed, be varnished, to keep it from imbibing moisture, which would conduct the electricity to the earth. A similar precaution must be used with glass pillars, for a very small quantity of moisture, which is so apt to be condensed upon their surface, would render it difficult to proceed with a course of experiments. The varnish commonly used for glass, is sealing-wax, which is laid on either by melting it, or when it is in a state of solution. It is most easily laid on by melting it, for nothing more is necessary than to heat the glass, and when it is warm enough, to rub a stick of sealing-wax over it till it is completely covered. When the sealing-wax is employed in a state of solution, it must be put into alcohol in small pieces, and when dissolved, the glass must be covered with it by means of a camel's hair pencil. Several coats will be necessary. This method, though more troublesome, makes a smoother covering than the other. Glass pillars, after having been varnished, not only attract less moisture than before, but are more easily freed from it when acquired. When they require wiping, a warm piece of silk, such as a handkerchief, is the most suitable material to use.

With respect to the glass of which the cylinder is made, the

kind called white flint, or English crystal, generally used for table-glasses, is most approved. It is an important point to have it well annealed, that is, it should be kept in an oven, or covered with hot ashes, and suffered to cool in the slowest manner possible. It is not very material, whether the glass be thin or thick, though thin is perhaps preferable, if it be but strong enough to bear making the experiments. Some kinds of glass, we have observed above, are not so fit for electric purposes as other kinds; but a cylinder which is faulty from the nature of the glass, may be improved by lining it with a good electric. A proper composition for this purpose, may be made of four parts of Venice turpentine, one part of rosin, and one part of bees-wax. These ingredients must be boiled together for about two hours, over a gentle fire, and stirred very often: afterwards the composition must be left to cool, and reserved for use. To line a cylinder with this mixture, a sufficient quantity of it must be broken into small pieces and put within the cylinder, which must be uniformly heated, by turning it before the fire, and when the composition is melted, it must be spread equally over all the interior, so as to be about the thickness of a sixpence.

It is not uncommon to revolve the cylinder by means of a multiplying wheel; that is, the winch is affixed to a wheel which turns, either by teeth or by a band, another smaller wheel on the axis of the cylinder. By this means the cylinder is revolved about four times for the winch once; but these contrivances are apt to be often out of order, and to make a noise which is disagreeable; besides, they add nothing to the real power of the machine, while they increase its complexity and expense. A velocity of about five feet per second almost destroys the excitation of electricity; it is extent of surface, rather than velocity, which is essential to the formation of a powerful machine; the cylinder of which may be turned with sufficient rapidity by means of a winch upon the same axis. The predilection for multiplying wheels originated at a time when the subject had been but little examined.

The cylinder, conductor, rubber, and pillars of the electrical machine should, when it is in use, be perfectly dry, and to ensure this they should be rather warm than otherwise. When therefore it is to be employed in cold or damp weather, it should be set before a fire for some time, and every part well rubbed with warm flannel or silk, and when the least damp is suspected, the rubber should be taken off and dried separately. The ends of the cylinder may be covered with varnish or sealing-wax, in the same manner as the pillars, to prevent the

effects of moisture, as the ends are not so easily rubbed dry as the face of the cylinder.

The machine being supposed to be in order, and a communication made between the rubber and the ground, by means of a chain or piece of wire attached to it; on turning the cylinder with the winch, the electric fluid, in the form of sparks, accompanied with a snapping noise, may be drawn from the prime conductor, by presenting to it the knuckle, or any blunt uninsulated conductor. If any pointed body, such as a needle, be presented to the conductor while the cylinder is turned, a star or globule of light will be seen at the point, but no noise will be heard.

When the communication between the rubber and the earth is removed, and the same sort of communication is, instead of it, made between the earth and prime conductor; on presenting the needle to the rubber, a brush or pencil of light will be observed at its point. In the former case, that is, while the rubber communicates with the earth, the electricity of the conductor is positive, and it passes off through the needle to the earth: in the latter case, the electricity is negative, for the glass has taken from the insulated rubber all its electricity, which is conveyed from the glass to the earth by the prime conductor; therefore, on presenting the needle, the rubber draws through it, from the earth, electricity to compensate what it has lost. By this means may negative or positive sparks be obtained at pleasure, and it will be found that the former are more pungent than the other. Another cylinder, like the prime conductor, is often attached to the rubber, for the purpose of drawing strong negative sparks. This second conductor is therefore called the *negative conductor*, while the other is called the *positive conductor*.

The Plate Machine.

When glass was first used as the electric of a machine, the form of a globe was adopted; but afterwards the cylinder, as above described, was found more convenient and economical, and entirely superseded the globe. Dr. Ingenhouz, however, introduced the use of a flat cylindrical plate, turning on a horizontal axis in the manner of a wheel, and the machine thus constructed has many good properties; it is simple, elegant, compact, and powerful. A representation of it is given at fig. 3, pl. I. On a stout board GH, are firmly jointed two uprights LM, which are united for the purpose of greater steadiness by the cross piece F. The plate OP, is ground truly flat, and polished in the manner looking-glasses are made, and a hole is

made in its centre, by which means it can be fitted upon an axis, the form of which is shewn at fig. 4. The part *a* of this axis is thicker than any other part of the side or half *a b*; at *c* the axis is screwed; and this screwed part is rather less in diameter than the part *a*, but, by the depth of the thread at least, it is more than the thickness of the part *c b*. The hole in the centre of the plate just fits the part *a*, so that one side of it lies flat against the shoulder *d*; another shoulder *f*, being tapped so as to screw upon *c*, will therefore, when screwed on, make the plate as tight as may be necessary, because the screw reaches a little within the perforation of the glass. The direction in which the plate is revolved, should be contrary to that which would open the screw. A left-handed screw will therefore be the most convenient.

Plate machines have at least four rubbers, two on each side of the glass. These rubbers are made of red leather stuffed with curled hair, like those of the common machine, but they are connected together in pairs, and made to press against the glass by screws, one of which is shewn at *h*, fig. 3. To these rubbers are attached flaps of black oiled silk, *k k*, on one side of the glass. The prime conductor is supported on a glass pillar, and has a semi-circular arm at the end next the plate, terminated by two spheres, on the side of which next the glass, are points to collect the electric fluid.

From the great surface exposed by a plate, these machines are susceptible of a strong excitation, and they have of late been preferred by lecturers in general; they would probably be still more common, were it not for the great expense of ground glass, when of large diameter.

The insulation of the rubbers, and consequently the obtaining of negative electricity, is not so easily performed by the plate machine as the cylinder one: the means yet adopted to accomplish this have in general been rather complex. It may, however, be done by making the rubbers in the form shewn at fig. 5, the part *x* being glass, and cemented by a cap at the top and bottom to the rubber and the frame; chains or wires must be used when the rubbers are intended to communicate with the earth for the supply of positive electricity.

The most powerful electrical machine ever made was of this description. It was constructed by Cuthbertson, a celebrated philosophical instrument-maker in London, for Teyler's museum, at Haarlem. It consisted of two circular plates of glass, each 65 inches in diameter, and made to turn upon the same horizontal axis, at the distance of 7½ inches from one another. These plates were excited by eight rubbers, each 15½ inches long. Both sides of the plates were covered with

a resinous substance, to the distance of 16½ inches from the centre, not only to render the plates stronger, but likewise to prevent any of the electricity from being carried off by the axis. The prime conductor consisted of several pieces, and was supported by three glass pillars 57 inches in length. The plates were made of French glass, as this is found to produce the greatest quantity of electricity next to English flint, which could not be procured of sufficient size. The conductor was divided into two branches, which entered between the plates, and collected the electric fluid by means of points from their inner surfaces only. The force of two men was required to work this machine; but when it was to be kept in action for any length of time, four were necessary. By 160 turns of this machine, Dr. Van Marum charged 225 jars, each containing one foot of coated surface.

The Leyden Phial, or Electric Jar.

Electricity, derived from the conductor of a machine, is accumulated, and for a time preserved, by means of electrics coated with conducting substances. Glass is the electric most usually employed, and the form generally selected is that of a bottle or jar. "Leyden phial," and "electric jar," are synonymous terms. This part of the electrical apparatus is represented by fig. 6, pl. I. The jar is coated with tin-foil, both within and without, to the height *a b*; the tin-foil is held upon the glass by gum-water, flour-paste, or any other slight cement which is not very combustible; varnish, if used, might be set on fire in using the jar. From the height *a b* to the mouth of the jar, both within and without, the glass is left uncoated, in order that no communication of the electric fluid may occur without an intentional application for that purpose. The mouth of the jar is covered with a piece of wood, which is baked and varnished, consequently a non-conductor like the glass itself. In this wooden cover is inserted a wire with a knob at the top; the wire descends, and is in contact with the inside coating of the jar, either directly, or by means of a small piece of chain, attached to its lower end; the chain is not so apt to scrape off the coating as the wire itself would be, in wide-mouthed jars, or those without a neck, a large cork is fixed at some distance from the bottom, through which the single wire from the knob passes, and terminates in several branches that touch the inside coating in different parts.

To charge the electric jar, the knob *k* of the wire is held to the prime conductor of the machine, while the outside of the jar communicates with the earth, by means of the table on

which it rests, or the hand in which it is held. When the machine is in order, a few revolutions of the winch charges the jar, and renders it capable of exhibiting its surprising properties. The jar is said to be positively electrified, when the inside receives the electric fluid, and the outside is connected with the earth; on the contrary, when the outside receives the charge, which is done by insulating it while the inside communicates with the earth, the jar is said to be negatively electrified. In either state, if a communication be made between the two coatings, by any conducting substance, the equilibrium is immediately restored with a flash. A jar cannot be charged plus, unless there be a communication between its outside coating and the earth, except in a moist atmosphere; nor minus, unless its inside coating communicates with the earth.

In selecting jars for electrical purposes, care should be taken to have the glass equally thick in every part. When a jar is in this respect much defective, if strongly charged, it will break in the thinnest part. The thinner the jar, the more easy it is to charge it; thin jars are therefore proper for machines of inconsiderable power, but the total charge they will receive is not equal to that of a strong jar.

If the jars employed be sufficiently wide at the mouth to admit of the hand, they may be coated with tin-foil within almost as easily as on their exterior; but when they have but a narrow opening, brass or other metallic filings, may be mixed up with gum-water, then poured in, and the jars turned till the mixture touches every part required.—The amalgam used for silvering glass globes, (a recipe for which is given in another part of this work,) also affords a ready method of coating narrow-necked jars.

It is necessary that the coating of a jar should not extend very near the top on either side, otherwise it will discharge itself. A distance of two or three inches should always be allowed.

If a slip of writing-paper, about one-third of an inch broad, be pasted round an electrical jar, so that its bottom edge shall just be in contact with the upper edge or top of the outside coating, the air will have less power to draw off its charge than before.

The Electric Battery.

The electric battery is formed by combining a number of jars in the manner shewn by fig. 7, pl. I. A wooden box of a size adapted to the number of jars it is to contain, and not quite so deep as the jars are high, is divided into compartments, each of which will just receive one jar. By this means the jars are prevented from being jammed against each other. The

vertical wires which proceed from each row of these jars are screwed or otherwise fastened to a horizontal wire, WX, which is knobbed at its extremities. These horizontal wires connect all the jars of the same row, and the rows are connected by shorter wires, as QRS, which proceed from them. The short wires QRS, are moveable upon their respective horizontal wires, which pass through a ring in one of their extremities, and therefore, by placing them in contact with the horizontal wires, or drawing them back, either the whole or any number of the rows of jars in a battery may be employed at once.

When a battery is always intended to be used entire, the best construction is, to have a ball at the top of every vertical wire as in a single jar, and to let the horizontal wires pass through these balls both across the length and breadth of the battery, so that they will form sqnares, at the corners of which are the balls. By this arrangement, the passage of the electric fluid is less interrupted than in the former. The vertical wires may either be supported by corks fixed within the jar, or by a wooden cover.

To render more complete the communication of the outside coatings of the jars with the earth, the compartments of the box are entirely lined with tin-foil; and on one side of the box is a hole, through which passes a metallic hook, F, which is in contact with the lining of the box, and consequently with the outside coatings of the jars. With this hook may be connected a wire communicating with the earth, also any substances through which the charge of the battery is desired to pass.—A handle, K, is fixed on each side of the wooden box, for the purpose of conveniently moving the battery.

In electrical experiments it is a general rule to avoid moisture, yet by blowing into jars from the mouth, which is best done through a tube, they are not less liable to break than before, but they will bear a charge one-third stronger than they would otherwise admit.

A powerful battery may be formed of common green glass bottles, such as are used for wine, porter, &c. They must be coated and furnished with a wire in the same manner as ordinary jars.

When any difference is known to exist in the strength of the jars employed to form a battery, the weakest jars should be placed on the side furthest from that where the discharge is made. By observing this rule, Brookes found that he could use cracked jars, after having repaired them with the following composition:.Take of Spanish white eight ounces; heat it very hot in an iron ladle, to evaporate all the moisture; and when cool, sift it through a lawn sieve; add three ounces of

pitch, three-quarters of an ounce of rosin, and half an ounce of bees-wax; combine these ingredients over a gentle fire, stirring them frequently for nearly an hour; then take the composition off the fire, and continue the stirring till it is cold.

Plates or squares of glass, coated on both sides with tin-foil, to within about half an inch of the edge, will form a good battery, but they do not retain the charge so long as jars.

The power of a battery is estimated according to the number of square feet which it contains of coated surface.

When a battery is not found to take a charge in the manner expected, it may be suspected that one or more of the jars is cracked, in which case no charge can be given until the accident is repaired. No method has yet been discovered which so effectually prevents jars from being struck through by the electric discharge, as that discovered by Brookes, whose recipe for mending jars has just been given. His plan consists in placing writing-paper between the tin-foil coating and the jar. The tin-foil is first pasted on the paper, and then the latter upon the glass. After adopting this expedient, he never had a jar struck through, although some that he employed were so large as to contain three gallons each. On the contrary, he found that jars coated with brass filings, mixed up with a cement composed of pitch, rosin, and wax, were struck through with a very low charge. Paper, which answered so well, is neither a good insulator nor conductor: the cement which produced so many disasters is composed of electrics; these facts point to the probable effects of other substances applied to this purpose.

In discharging electrical jars or batteries, the electric fluid passes in the greatest quantity through the best conductors, and by the shortest course. Thus, if a chain and a wire, communicating with the outward coating, be presented to the knob of a jar, the greater part of the charge will pass by the wire, because the chain is the worse conductor, from the want of perfect continuity in the links. When the discharge is made by the chain only, sparks are seen at every link, which would not happen if they were in contact: and as it requires considerable force in stretching the chain, before the sparks cease to be seen, a proof is thus obtained that a strong power of repulsion is to be overcome, before the contact of bodies ensues.

The Discharging Rod.

The common discharging rod, which is represented at fig. 8, pl. I, consists of a glass handle, M, cemented into a brass socket, N. Two wires, PP, slightly incurvated towards each other, are jointed into the brass socket N, by which means

their extremities may be brought together, or separated as far as required. The wires are pointed at the extremities, but being screwed also at a little distance from the point, each of them admits of a small sphere or knob being screwed upon it.

To discharge a jar with this rod, the wires are opened till their extremities will reach from the knob of the jar to its outside coating, and the discharge immediately follows the establishment of the communication between these two parts; a battery is discharged in the same manner, by touching, with one limb of the instrument, the hook, or the wire attached to the hook, in contact with the outside coatings, and with the other limb touching one of the wires communicating with the inside coatings.

In making the discharge, the electricity only passes through the metallic part of the instrument, and therefore the person who holds by the glass handle, receives no shock. Some part of it, however, might reach him, if the surface of the glass happened to be damp.

When the discharge is used with knobs at its extremities, the discharge is made with a flash and a report, but when points are used, the discharge is silent, and invisible also, except in the dark.

Henley's Universal Discharger.

This is a very convenient instrument, and is used in a great number of experiments, to make the electric discharge through or upon particular substances. The base of the instrument, AB, fig. 9, pl. I, is a flat board, generally made about fifteen inches long, four broad, and one thick. CD are two glass pillars, cemented into brass sockets which are screwed to the board AB. These pillars are also furnished with brass caps at their tops, and through short tubes, *bb*, connected with them, pass the wires FG. Within each of the tubes *b b*, is a spring, which pressing upon the wire, keeps it at all times from being loose. These wires have three motions, for the purpose of placing them in any situation: the first motion is backward and forward, through the tubes *b b*, and consequently in the same direction with these tubes; the second is a vertical motion, by means of a joint at *c c*; the third a horizontal motion, produced by the lower part of the joints *c c* being cylindrical, and turning in sockets. Each of the wires is furnished with an open ring at one end, and at the other has a brass knob; but the knob only slips upon the extremity of the wire, which is pointed, and enters a socket containing a spring; it is therefore put on or removed in a moment. K is a strong circular piece of wood,

about five inches in diameter, and the upper surface of which is inlaid with a slip of ivory. The pillar I is hollow, and this hollow receives a stout cylindrical stem from the underside of the tablet K, which may therefore be fixed at different heights by means of a small screw *m*.

To this instrument belongs the small press, represented at fig. 10, which consists of a tablet and stem that can at any time be substituted in the socket I, fig. 9, for the tablet K; on the top of it are placed two oblong pieces of board, which are pressed together by means of two small screws, *a a*. Between these boards may be placed any substance which requires pressure while the electric shock is sent through it.

Electrometers.

Instruments for ascertaining the degree in which any body is electrified, or the presence or kind of electricity, are called *electrometers*.

Dr. Priestley recommends, as one of the simplest electrometers, a single fibre of silk as it comes from the worm, which being extremely light and flexible, very readily discovers the electric properties of any body, by being first attracted and then repelled by it; and as this substance, at the same time, has a power of retaining its electricity very strongly, we have thus an opportunity of determining whether the body, from which it received the electricity, was positive or negative.

Next to the use of a single fibre, to detect electricity, Canton's electrometer is the most simple. To form this instrument, a thread of linen, *r s t*, fig. 11, pl. I, is fastened to a thread of silk, *s v*. To each extremity of the linen thread is fastened a small cork or pith ball. Taking hold of the silken thread, present these balls to any body of which it is required to know whether it is in an electrical state or not, and if it have any electricity to communicate, after the balls have been withdrawn, they will repel each other, and not collapse for a considerable time afterwards. The further they repel each other, the stronger is the electricity they have received.

Cavallo, to avoid the obstruction of the wind upon Canton's electrometer, contrived to enclose the cork balls in a bottle, and by this means formed a much more elegant and complete instrument, of which the following is nearly his description: CDMN, fig. 12, is an open glass vessel, narrower at the top than at the bottom, and cemented into the wooden piece AB, by which part the instrument is held when it is to be presented to the atmosphere, or it may be set down upon it on a table for other experiments. This wooden piece also serves to screw the instrument into its wooden case O. The upper part of

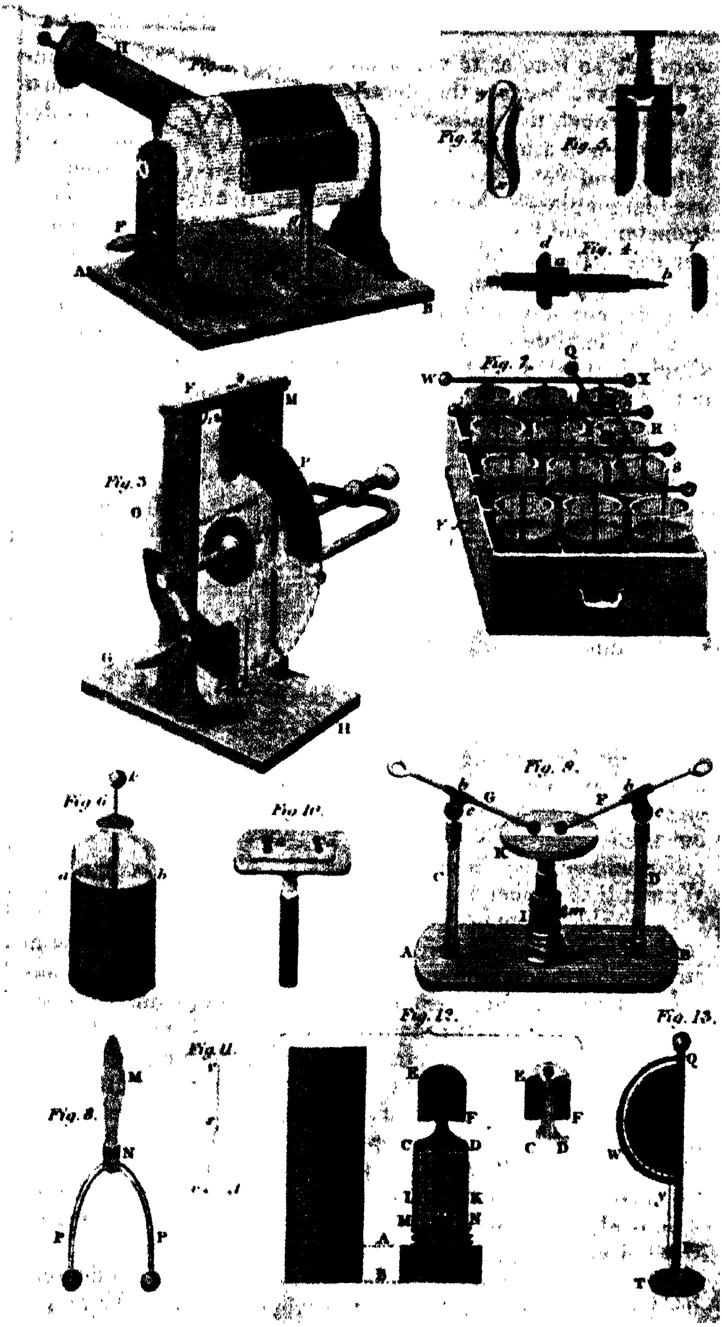
CDMN, is tapering like the neck of a phial, and a short glass tube is cemented into it, so as to project a little above and a little within the neck of the former. Then the upper part of the instrument, from CD to L, is covered with sealing-wax, in the manner described for covering the pillars of the electrical machine. The inner part G, of the small glass tube, is also covered with sealing-wax. Into this tube a brass wire is cemented, the lower part H of which is flattened, and is perforated with two holes: the upper part L is formed into a screw, into which the brass cap EF is screwed. The office of this cap is to defend the upper part of the instrument from the rain. The corks, P, of this electrometer, which are generally globular, or in some form approaching to that, are as small as can be made, and are suspended by exceedingly fine silver wires, the upper parts of which are formed into rings, which pass through the holes at H, and are thereby so loosely suspended, that they are caused to diverge when the brass cap E is exposed to a very slightly electrified atmosphere. IM and N are two narrow slips of tin-foil stuck to the inside of the g...s, and communicating with the wooden bottom AB. The silver wires must be long enough to allow the cork balls to touch the tin-foil, in order that the electricity they have received may be communicated to the earth, as its accumulation would disturb the free motion of the corks. This instrument will shew signs of electricity, when the cap is rubbed or struck with a silk handkerchief; yet its delicacy has been further increased by Bennet, who, for the silver wires and cork balls, substituted strips of leaf-gold, made four-fold; with this alteration, however, the instrument is less portable than before. Cavallo observes, that fine threads, stiffened with glue, and used without any balls, will be found nearly as sensible as the slips of leaf-gold. Electrometers of this description are adapted to shew the presence and kind of electricity rather than its degree. The balls will diverge, whether the electricity they receive be positive or negative; but if the electricity be positive, they will collapse, or at least approach near each other, when the cap is touched with an excited stick of sealing-wax, the electricity of which is negative; but if they separate further on the approach of the wax, the balls are negatively electrified. If excited glass be used, as its electricity is opposite to that of the wax, an opposite conclusion must be drawn from its effect. To try the electricity of the air, fogs, or clouds, with this instrument, it is only necessary for the observer to take it out of its case, and hold it up a little above its head, by the wooden bottom.

Saussure suggested an improvement of Cavallo's electrometer, in which the fine wires by which the balls were suspended

were not so long as to reach the tin-foil pasted on the inside of the glass; because the electricity, when strong, would cause them to touch the tin-foil twice consecutively, and thus deprive them in a moment of their electricity. To prevent this defect, and yet leave them a sufficient degree of motion, he used larger glasses than are generally applied to Cavallo's electrometer; and found two or three inches diameter to be a proper size. But as it is necessary to carry off the electricity which may be communicated to the inside of the glass, and thus be confounded with that which belongs to those substances that are under examination, four pieces of tin-foil should be pasted on the inside of the glass; the balls should not be more than one-twentieth of an inch in diameter, suspended by silver wire, moving freely in holes nicely rounded.

The degree of electricity is measured by the quadrant electrometer, which is a much more common instrument than the last mentioned, almost every electrical machine being furnished with one. QR, fig. 13, is a rod of box-wood, terminating with a knob at the top, and with a slender pin like a pivot at the bottom, by which means it can readily be placed upon the small stand T, or in a hole upon the prime conductor of the electrical machine, or to the brass knob of a jar. W is a semi-circle of ivory, a quadrant of which is graduated; it is attached to the rod QR, and at its centre is fixed a piece of brass, from which projects a small pin or axis. From this axis is suspended a very slender and light piece of box-wood *y*, with a cork or pith ball at its lower extremity. When this instrument is not electrified, the rod or index *y* hangs parallel to the pillar QR, but the moment it is electrified, the index *y* is repelled by the pillar, and begins to move over the face of the ivory semi-circle W, and the number of degrees or extent of the arc intercepted between the commencement and termination of its range, shews the intensity of the charge to which it is exposed. This instrument is made as free from corners or sharp edges as possible: the pillar and index are round and smooth, and the edges of the semi-circle well rounded; and as it is composed of imperfect conductors, it is not apt to dissipate the electricity of the jar or prime conductor to which it is applied; but if, upon trial in the dark, it is found to collect the electric matter, it may be suspected to be damp, and should be brought within the warmth of a fire. The semi-circle cannot be too dry, but the pillar may be rendered so dry as not to receive the electric fluid readily enough to have a proper influence on the index; this defect, however, may be remedied by damping it. The index of the electrometer never rises higher than 90 degrees, because the repulsion of the stem, when it is at 90 degrees, is

ELECTRICITY.



equal on both sides of it; in charging a large battery, it will seldom rise so high as 90 degrees; and when it rises above 80, the charge may be considered strong.

Insulating Stool.

The insulating stool, represented at fig. 1, pl. II, is merely a mahogany board with glass feet, which are varnished like other insulating supports that are made of glass. By standing upon this stool, the human body may be insulated; and when, for medical purposes, it is necessary for a person to be insulated for a considerable time, it should be large enough to admit of a chair to be set upon it. The usual fault of insulating stools is, that the feet are imperfectly fastened, and apt to come out. This may be prevented, if the feet be first cemented into brass sockets of at least an inch and a half deep, and these sockets screwed to the wood; but if the glass feet be let into the wood, they will either not have sockets sufficiently deep, or they will be thick and clumsy.

Electrical Experiments.

To shew the Course of the Electric Fluid.

1. Charge the jar, fig. 2, pl. II, by holding its knob to the prime conductor during a few turns of the machine; set the jar upon a table, and present one of the pointed extremities of the discharging rod, M, fig. 8, pl. I, about the distance of an inch from the knob, while the other pointed extremity is presented at an equal distance from the outside coating of the jar. The silent discharge of the jar will immediately commence, and the inside being electrified positively, it will be observed that the point *e* of the discharging rod is illuminated with a star, and the point *f* with a brush or pencil; because the electric fluid, passing from the inside to the outside of the jar, enters the point *e* and issues at the point *f*. But if the jar is electrified negatively on the inside, as it is in that case always positive or in the opposite state on the outside, the pencil of rays will appear upon the point *e* and the star upon the point *f*: for the electric fluid will then have to pass in an opposite direction.

It must be observed, that this and all other experiments in which the electric light is to be seen with advantage, should be performed in the dark.

2. The prime conductor invented by Henley, and called *Henley's luminous conductor*, is well adapted to shew the course of the electric fluid. The middle part, EF, fig. 3, pl. II, of this conductor, is a glass tube about eighteen inches long, and three or four inches in diameter. To both ends of this

tube the brass caps FD, BE, are cemented air-tight; one of them has a point C, by which it receives the electric fluid, when set near the excited cylinder or plate of the machine, and the other has a knobbed wire G, from which a strong spark may be drawn; and from each of the caps FD, BE, proceeds a knobbed wire within the glass tube. The brass cap FD, or BE, is composed of two parts, that is, a tube F, cemented to the glass tube, with a ball D, which is screwed upon the tube F, and at the end B is a stop-cock, which is closed after the conductor has been exhausted of air by the air-pump, and the ball G fitted upon its extremity. The supporters of this instrument are two glass pillars fastened in the bottom board H, like the supporters of an ordinary prime conductor. When the glass tube of this conductor is exhausted of air, and the brass ball is screwed on as represented in the figure, then it is fit for use, and may serve for a prime conductor to an electrical machine. If the point C of this conductor is set near the excited cylinder of a machine, it will appear illuminated with a star; and at the same time the glass tube will appear to be wholly illuminated with a feeble light, for the electric fluid becomes greatly diffused in vacuo; but from the knobbed wire that proceeds within the glass from the piece FD, will issue a pencil of light, and the opposite knob will appear illuminated with a star, which, as well as the pencil of rays, is very distinctly discernible among the other light, that occupies the greatest part of the cavity of the tube. If the point C, instead of being presented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reversed; the knob which communicates with the cap FD appearing illuminated with a star, and the opposite knob with a pencil of rays; because in this case the direction of the electric fluid is just the contrary of what it was before; it then going from D to B, and now coming from B to D. If the wires within the tube EF, instead of being furnished with knobs, be pointed, the light is still seen, but not so vividly.

3. The *conducting glass tube* is an experiment on the same principle as the foregoing. To form it, take a glass tube, about two inches in diameter, and two feet long; fix to one of its ends a brass cap, and to the other a stop-cock or a valve; and exhaust the tube by means of an air-pump. If this tube be held by one end, and its other end be brought near the electrified prime conductor, it will appear to be full of light whenever a spark is taken by it from the prime conductor, or from a charged jar. This experiment may also be made with the receiver of an air-pump: take, for instance, a tall receiver,

clean and dry; and through a hole at its top insert a wire, which must be cemented air-tight. The end of the wire within the tube must be pointed, but not very sharp, and the other end must be furnished with a knob. Put this receiver upon the plate of the air-pump, and exhaust it. If now the knob of the wire at the top of the receiver be touched with the prime conductor, every spark will pass through the receiver in a dense and large body of light, from the wire to the plate of the air-pump. —The communication between the receiver and the prime conductor may be made by means of the discharging rod, in this case, as well as in others where it would be inconvenient to lift the vessel through which the discharge is to be sent.

The artificial Aurora Borealis.

Take a phial in shape and size like a Florence flask, with a stop-cock adapted to it. Close the stop-cock after exhausting the phial of air, and rub the glass in the usual manner for exciting electrics, when it will immediately appear luminous within, with a flashing light, that forms a striking miniature resemblance of the aurora borealis or northern lights. Instead of the glass phial to produce this effect, may be used a glass tube, exhausted of air, and hermetically sealed.

The phial used in this experiment may be made luminous, if held by either end while the other is presented to the prime conductor, the strong flashing light which then appears, will remain for some time after it has been removed from the prime conductor; and even several hours after it has been withdrawn, on grasping the phial with the hand, strong flashes of light will reappear.

To shew Electric Attraction and Repulsion.

Two distinct bodies in the same electrical state repel each other, whether they have both more or less than their natural share of electricity; but if the one has more or less than the other, attraction takes place: this is a summary of the doctrine of electrical attraction and repulsion, and explains the various experiments which bring these properties into action.

1. If a bundle of hairs or feathers be hung upon the prime conductor, the moment they are electrified by working the machine, they begin to fly from one another, and they will not again collapse until the electricity is taken off. A fanciful mode of shewing this experiment consists in making the form of a human head, see fig. 4, pl. II, with hair on, and upon placing this image upon the electrified conductor, the hair immediately stands up like "quills upon the fretful porcupine."

2. Electric attraction and repulsion may be agreeably shewn by means of a glass tube and feather. When the tube is excited, by being drawn through the hand, or a flannel rubber, the feather, when brought near it, will be attracted, and jump to the tube; then, after taking some time to get fully saturated with the electric matter, (because, being a bad conductor, it can receive it but very slowly,) it will suddenly jump from it, and fly towards the next conductor, to which it will impart the redundant electricity it has acquired. If no other body happen to be in the way, it will tend towards the ground; but by holding under it the electrified tube, it will still be repelled, and therefore suspended, and may be driven to any part of the room, as it will always avoid the tube until it has touched some conducting substance. To continue this experiment for some time, the air should be tolerably dry.

A remarkable circumstance, in performing this experiment, is, that the feather always presents the same side to the glass tube, because, being a bad conductor, as just observed, it is only that side of it which it presents to the tube, that is possessed of the same electricity as the tube.

3. Another common experiment, to shew electrical attraction and repulsion in an amusing form, consists in suspending a flat plate of metal A, fig. 5, from the prime conductor, and underneath it, at the distance of three or four inches, another plate B, of the same description, fixed upon a stand. Upon the lower plate may be placed some small figures of men and women, cut out of paper in such attitudes as fancy may suggest. As soon as the upper plate, by turning the machine, is electrified, and therefore in an opposite state to the lower plate, it has a disposition to attract the lower plate to it, in order to restore the equilibrium; but as the weight of the latter is too considerable to be overcome, the figures placed upon it become the mediators, and accordingly they immediately rise upon their feet, and jump alternately from one plate to the other, thus exhibiting a kind of dance, performed with the most sportive vivacity.

4. Insulate two bodies, and charge one of them plus, the other minus. Then suspend between them, by a silken string, an artificial spider, of which the body may be cork and the legs the fibres of feathers; the spider will move from one of the insulated bodies to the other till their charge is equalized.

5. Place a cap or covering of metal upon the two extremities of a glass tube four or five inches long, and enclose in the tube some saw-dust or pith-balls; then charge one of the plates plus and the other minus, when, as glass is a non-conductor, the

equilibrium can only be restored by the saw-dust or balls, which will accordingly jump up and down till the charge of each plate is the same.

6. A great variety of experiments of this nature may be tried, but after adverting to the amusing one called the electric bells, we must leave the subject to the invention of the reader. From a small pedestal A, fig. 6, rises a stem F, which supports a small bell B. From this bell rises a glass tube, to the top of which is cemented a brass ball, C, with four wires of the same metal fastened in it at equal distances. From each extremity of these wires, which terminate in small knobs, hangs, by a brass chain, a small bell, like the bell B. From the middle of each wire, hangs, by a silken thread, a small brass ball. The bells are all suspended in the same plane, and the balls *a b c d* are at such a height that they will, if caused to vibrate, equally strike near the base, the bell in the centre, and their respective bells banging from the wires. From this construction it will be understood, that the brass balls *a b c d* are insulated, because they are suspended by silk; but the bell B has a communication with the earth, because its support is a conductor, while it is separated from the brass knob C and the wires, by the non-conductor or glass pillar. Connect the knob C with the machine, by means of a chain or wire, and electrify it; the wires and bells suspended from them will be electrified at the same instant. As soon as this is done, the bells attract the insulated clappers, and having communicated to them a little electricity, immediately repel them. The clappers now fly to deposit the electricity they have received upon the central bell. They are then again in a condition to be attracted by the suspended bells, and again return to the centre bell on being repelled, and this alternate motion continues, accompanied of course by the ringing of the bells, till the electrification of the ball C is discontinued, or the communication of the bell B with the earth cut off.

To produce Flashes of Electric Light.

If two persons, one standing upon an insulated stool, and communicating with the prime conductor, while the other stands upon the floor, hold in their hands plates of metal, in such a manner that the flat sides of the plates shall be opposite each other at the distance of about two inches; on strongly electrifying the insulated person, dense and frequent flashes of light will be observed between the plates, forming a kind of artificial lightning.

To set fire to Inflammable Spirits.

To the knob *k* of the prime conductor, fig. 1, pl. 1, when electrified, present a small quantity of spirits of wine, held in a spoon, and rather warmed, and it will immediately be fired by the spark. The same experiment may be conveniently performed by putting the spirits into a small dish, which, by means of a wire from the bottom of it, may be placed upon the prime conductor.

If a person, standing upon the insulating stool, and communicating with the prime conductor, hold the spoon with the spirits in his hand, another person standing upon the floor may set fire to the spirits, by presenting to it any conducting substance, or even his finger, if it could be drawn back with sufficient rapidity to prevent its being scorched with the flame. —The experiment may be reversed; the person upon the floor may hold the spirits, and an insulated and electrified person may set fire to it by its touch.

If an insulated and electrified person hold a vessel containing ether in his hand, it will inflame without being touched by any foreign body.

The Visible Electric Atmosphere.

This experiment was contrived by Beccaria. GI, fig. 7, pl. II, represents a receiver with the plate of an air-pump. In the middle of the plate IF, a short rod is fixed, having at its top a metal ball, B, nicely polished, and the diameter of which is nearly two inches. From the top of the receiver, another rod AD, with a like ball A, proceeds, and is cemented air-tight in the neck C; the distance of the balls from one another being about four inches, or rather more. If, when the receiver is exhausted of air, the ball A be electrified positively, by touching the top D of the rod AC with the prime conductor, or an excited glass tube, a lucid atmosphere appears about it, which, although it consist of a feeble light, is yet very conspicuous and well defined, at the same time that the ball B has not the least light. This atmosphere does not exist all round the ball A, but reaches from about the middle of it to a small distance beyond that side of its surface which is towards the opposite ball B. If the rod with the ball A be electrified negatively, then a lucid atmosphere, like that above described, will appear upon the ball B, reaching from its middle to a small distance beyond that side of it that is towards the ball A; at the same time the negatively electrified ball A remains without any light. The experimenter must take care not to electrify the ball A too

much, or the electric fluid will pass in a spark from one ball to the other, and the experiment will not have the desired effect.

"By this elegant experiment," says Cavallo, "we have an ocular demonstration of the theory of a single electric fluid. We see that electricity consists of one uniform homogeneous fluid, and not of two, viz. the vitreous and resinous, as some have supposed; for, if the positive and negative electricity were two distinct fluids, attractive of one another, there should, in the above experiment, always appear two atmospheres; that is, one about the ball A, and another about the ball B; for when the ball A is overcharged with either fluid, it should shew that superfluous fluid on its surface, and this fluid should attract towards the ball A an atmosphere of the contrary fluid from the ball B. But this is not the case, for the lucid atmosphere is always on one ball, namely, that which is overcharged with the electric fluid: thus when the ball A is electrified positively, the superfluous fluid is visible on that part of it which is nearest to the ball B; because B, being in a contrary state of electricity, endeavours to attract it; but when the ball A is electrified negatively, it will attract the fluid proper to the ball B, which fluid on that account appears on the surface of B just in the act of leaping to the ball A."

The Spiral Tube and Illuminated Words.

Fig. 8, represents an instrument composed of a glass tube, with a knobbed brass cap at each extremity. Upon the outside of this tube are stuck small round pieces of tin-foil at the distance of about one-thirtieth of an inch from each other. If this instrument be held by one extremity, while the other is presented to the prime conductor, every spark it receives will cause sparks to be perceived between each piece of tin-foil, and thus afford the appearance of a spiral line of light upon the tube.

This experiment may be diversified by using a plain piece of glass, on which, by the manner in which the spaces between the pieces of tin-foil are left, may be delineated flowers, words, &c. as exemplified by the word "Panorama" on the plain piece of glass, AB, fig. 9; the knob C is presented to the prime conductor, and the spark makes its exit at B, where it communicates with the earth.

The Leyden Vacuum.

Coat a phial ten inches high, about three inches up the sides, with tin-foil; cement on its aperture a brass cap, containing a valve opening outwards, and from the cap let a wire with a

blunt point reach a few inches within the phial. Exhaust the phial of air, and then screw upon the brass cap a brass knob. This phial exhibits the direction of the electric fluid both in charging and discharging. If it be held by its bottom, and its brass knob be presented to the prime conductor positively electrified, it will be seen that the electric fluid causes the pencil of rays to proceed from the wire within the phial: and if it be discharged, a star will appear in the place of the pencil. But if the phial be held by the brass cap, and its lower coated extremity is presented to the prime conductor, then the point of the wire will appear illuminated with a star when charging, and with a pencil when discharging. If it be presented to a prime conductor electrified negatively, all these appearances, in charging and discharging, will be reversed.

The phial used in this experiment should be round at the bottom like a Florence flask, in order that, when it is exhausted of air, the pressure of the external atmosphere may be in no danger of breaking it.

The exhaustion of the phials and tubes used in electrical experiments, may, by those who have not the convenience of an air-pump, be accomplished with sufficient accuracy by means of a syringe. To use this instrument for exhausting, the piston should contain a valve opening outwards, and the phial, &c. another valve opening in the same direction, and the working of the piston will then exhaust the phial, over the valve of which it is screwed.

To pierce a Card, &c. by Electricity

Take a card, a quire of paper, or any similar material, and place it against the outside coating of a charged jar: keep the card in its situation by pressing against it one knob of the discharging rod, and with the other knob of the rod touch that of the jar. The discharge which will immediately follow, to restore the equilibrium of the two sides of the jar, will be found to have made one or more holes entirely through the card; and each hole will have a bur or raised edge on both sides, unless pressed rather hard against the sides of the jar. This double bur shews that the card is not perforated in the direction of the passage of the fluid, but by the expansion of its substance in every direction.

If, instead of paper, a very thin plate of glass, sealing-wax, rosin, or the like, be interposed between the knob of the discharging rod and the outside coating of the jar, the discharge will break these substances to pieces.

A small insect interposed in the manner of the card, though

not pressed, will be instantly killed by the discharge: and a discharge of six square feet will deprive a man of sensation for a time, if the head be made part of the circuit.

Effect of the Shock sent over the Surface of a Card or Glass.

Put the extremities of two wires upon the surface of a card, so that they may be opposite each other, at the distance of about an inch, then, by connecting one of the wires with the outside of a charged jar, and the other wire with the knob of the jar, the shock will be made to pass over the card; upon which, if very dry, a lucid track will be observed for some time after the explosion. If a piece of common writing-paper be used instead of the card, it will be torn to pieces by the discharge.

The card is an imperfect conductor, and the body over which the discharge is sent, should of course always be an imperfect conductor, or a proper electric. If, instead of a card, the discharge be sent over the surface of a piece of glass, this substance will be marked by an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. By this process, the glass is very seldom broken by the explosion; but Henley discovered a method of increasing the effect of the explosion upon the glass, which consists in pressing with weights that part of the glass which lies between the two wires, and which will be the path of the shock. He puts first a thick piece of ivory upon the glass, and places upon that ivory a weight at pleasure, from one quarter of an ounce to six pounds. The glass, under this management, is generally shivered into small pieces, and some of it is reduced into an impalpable powder. If it be so thick as to resist the force of the explosion, it is indelibly marked with the most lively prismatic colours. The weight laid upon the glass is always shaken by the explosion, and sometimes thrown quite off the ivory.

The universal discharger, fig. 9, pl. I, affords the most convenient method of performing this experiment.

To strike Metals into Glass, stain Paper, &c.

Take two slips of common window-glass, about three inches long, and half an inch wide; put a small slip of gold, silver, or brass leaf between them, and tie them together, or press them between the boards of the press, fig. 10, pl. I, belonging to the universal discharger, leaving out a little of the metallic leaf between the glasses at each end; then send a shock through

this metallic leaf, and the force of the explosion will drive part of the metal into so close a contact with the glass, that it cannot be wiped off, or even affected by the menstrua which otherwise would dissolve it. In this experiment the glasses are often shattered to pieces; but whether they are broken or not, the tinge from the metal will be found in several places, and sometimes through the whole length of both glasses.

If a chain which forms part of a circuit between the two sides of a charged jar, rest upon white paper, after the discharge has been made, the paper will be found stained with a blackish tinge at the juncture of the links. If the charge be considerable, the paper will be burnt through. If the chain repose upon glass, instead of paper, the glass will be stained, though only slightly.

The electric fluid, while passing through a perfect conductor, is invisible, but as the links of a chain are never in perfect contact, unless stretched to an extraordinary degree, in passing through a chain the light appears at every link, and if the links be very small, the shock sent through the chain will appear in the dark like a continuous line of fire.

Influence of Points on the Electric Fluid.

The influence of points, in drawing off the electric fluid, has frequently been alluded to in the course of the preceding pages, but to render the fact more conspicuous, we shall notice it among these experiments.

Place one hand upon the outside coating of a charged jar capable of giving a violent shock, and with the other hand hold a sharp-pointed needle, and keeping the point directed towards the knob of the jar, advance it gradually, until the point of the needle touches the knob. This operation discharges the jar; the pointed conductor employed has therefore had the effect of silently and gradually drawing off the redundant fluid it contained.

The more acute the point of the conductor made use of, the more powerful its effect. A prime conductor in which a needle is fastened, or held at a little distance from it, will afford but a feeble spark; for the electricity communicated to it passes rapidly off into the air.

The extremity of a point receiving the electric fluid, always assumes the appearance of a small globe or star; when imparting electricity, the appearance from it is that of a stream or pencil.

Several amusing experiments have been contrived, which depend upon the effects of points on the electric fluid.

1. Thus if a thin piece of metal, for example a piece of tin-plate, be cut in the form of a star, as shewn at fig. 10, pl. II, and be supported on its centre, by a wire from the prime conductor, as soon as the conductor is electrified, a brilliant speck of light will be seen at the extremity of every point, and if the star be turned swiftly on its centre, the appearance will be that of an entire circle of fire. As this experiment, for the light to be seen to advantage, should be performed in a darkened room, the operator may occasion some surprise among those unacquainted with the subject, by appearing to command the appearance or disappearance of the light; for on touching the prime conductor with the hand, the light will disappear.

2. The experiment called the *electric flies*, shews the effect of points in an amusing manner. Fig. 11, shews a combination of two of these flies, which consist of brass wires fastened, in the same plane, in a small brass centre-piece or cap; these wires are finely pointed, and bent at right angles near their extremities; and those of each fly are bent in the same direction, though the two flies with respect to each other have their points in a contrary direction. Each fly, *a b*, is exactly balanced, and will turn on its centre by the slightest impulse. The supporting wire *c* is fixed in the prime conductor, and as soon as it is electrified, the flies begin to turn with great rapidity, each in a contrary direction to that of its points, and in the dark the course of each fly will be marked by a line of fire. With a sufficiently powerful machine, the number of flies may be considerable, and by varying their sizes, distances, and position, an interesting spectacle will be produced.

The flies, in this experiment, turn the same way, whether positively or negatively electrified. This must be evident, when the cause of their motion is considered. When they are positively electrified, the electric fluid issuing from the points strikes the air, and causes their motion in a contrary direction to the points; and when they are electrified negatively, the stream of electricity which they solicit, impels them in the same direction. Under an exhausted receiver, no motion is produced, because the medium which still remains is not dense enough for the electric fluid to act upon with so much force as to overcome the friction of the flies upon their centres. Also, under an insulated receiver, containing only common air, the motion soon ceases, because the air and the glass soon become so much electrified, that the electric fluid ceases to escape from the points.

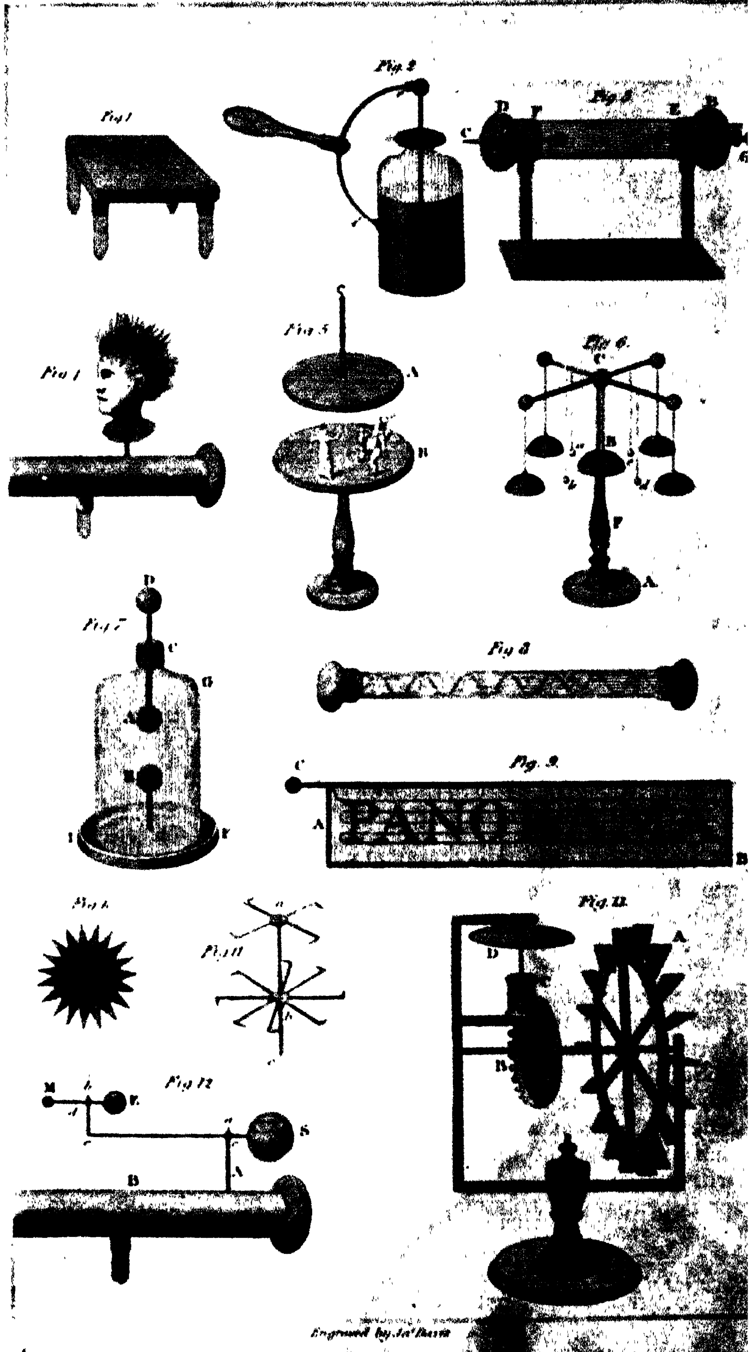
3. A great diversity of other experiments have been contrived to shew the power of points. one of them is the *electrical orrery*, represented at fig. 12. The sun and earth go round

their common centre of gravity in a solar year, and the earth and moon go round their common centre of gravity in a lunar month. These motions are represented by an electrical experiment as follows: the ball S represents the sun, E the earth, and M the moon, connected by wires *a c*, and *b d*; *a* is the centre of gravity between the sun and earth, and *b* is the centre of gravity between the earth and moon. These three balls and their connecting wires are hung and supported on the sharp point of a wire A, which is set upright in the prime conductor B of the electrical machine; the earth and moon hanging upon the sharp point of the wire *c*, in which wire is a pointed short pin, sticking out horizontally at *e*; and there is just such another pin at *d*, sticking out in the same manner, in the wire that connects the earth and moon.

When the working of the electrical machine is commenced, and consequently these balls and wires are electrified, the fluid that flies off horizontally from the point *c* and *d*, causes S and E to move round their common centre of gravity *a*, and E and M to move round their common centre of gravity *b*; and as E and M are light when compared with S and E, there is much less friction on the point *b* than upon the point *a*; so that E and M will make a much greater number of revolutions about the point *b*, than S and E make about the point *a*. The weights of the balls may be adjusted so that E and M may go twelve times round *b*, in the time that S and E go once round *a*.

4. The *electrical mill* is represented at fig. 13. A is the water-wheel, B the cog-wheel on its axis, C the trundle turned by that wheel, and D the running mill-stone on the top of the axis of the trundle. It may easily be turned by electricity, if instead of the round plate D for the mill-stone, there be a horizontal wheel on the axis of the trundle C, with spur-cogs, which will turn two trundles placed on its opposite sides; and on the top of each axis of these trundles, may be a round plate, representing a mill-stone; so that this model has all the working parts of a double water-mill, turning two mill-stones.

Set the mill near the prime conductor, and place the crooked wire, so that its point may be directed towards the uppermost side of the great wheel A; then work the electrical machine, and the stream of fire that issues from the point of the wire will turn the wheel; and consequently all the other working parts of the mill.



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The Thunder House.

The usefulness of metallic conductors applied to houses, and the bad effects which may result from the lightning striking upon a house not properly secured, may be shewn in a very convincing manner by the instrument represented at fig. 1, pl. III. A is a board about three-quarters of an inch thick, and shaped like the gable end of a house. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glass pillar CD is also fitted in a hole about eight inches distant from the base of the board A. A square hole ILMK, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a square piece of wood nearly of the same dimensions. It is mentioned nearly of the same dimensions, because it must go so easily into the hole, that it may drop off by the least shaking of the instrument. A wire LK is fastened diagonally to this square piece of wood. Another wire HI, of the same thickness, having a brass ball, H, screwed on its pointed extremity, is fastened upon the board A; so also is the wire MN, which is shaped into a hook at O. From the upper extremity of the glass pillar CD, a crooked wire proceeds, having a spring socket F, through which a double knobbed wire slips perpendicularly, the lower knob G of which falls just above the knob H. The glass pillar DC must not be made very fast to the bottom board B, but it must be fitted so that it may be easily moved round its own axis, by which means the brass ball G, may be placed nearer to or farther from the ball H, without touching the part EFG. Now when the square piece of wood ILMK (which may represent the shutter of a window or the like) is so fixed into the hole that the wire LK stands in the dotted representation IM, then the metallic communication from H to O is complete, and the instrument represents a house furnished with a proper metallic conductor: but if the square piece of wood ILMK, is fixed so that the wire LK stands in the direction LK, as represented in the figure, then the metallic conductor, HO, from the top of the house to its bottom, is interrupted at IM, in which case the house is not properly secured.

Fix the piece of wood ILMK, so that its wire may be as represented in the figure, in which case the metallic conductor HO is discontinued. Let the ball G be fixed at a perpendicular distance of about half an inch from the ball H; then, by turning the glass pillar DC, remove the former ball from the latter; by a wire or chain, connect the wire EF with the wire Q of the jar P, and let another wire or chain, fastened to the hook O,

touch the outside coating of the jar. Connect the wire Q with the prime conductor, and charge the jar; then, by turning the glass pillar DC, let the ball G come gradually near the ball H; and when they are arrived sufficiently near one another, the jar will explode, and the piece of wood ILMK will be pushed out of the hole to a considerable distance from the thunder-house. Now the ball G, in this experiment, represents an electrified cloud, the electricity of which strikes the house A, when it is arrived sufficiently near the top of it; and as this house is not secured with a proper conductor, the explosion breaks off a part, that is, knocks off the piece of wood ILMK.

Repeat the experiment with only this variation, viz. that the piece of wood ILMK be situated so, that the wire LK may stand in the situation IM, by which means the conductor HO ceases to be discontinued. In this case the explosion will have no effect on the piece of wood, which will remain in its place unmoved; a proof of the usefulness of the metallic conductor.

Unscrew the brass ball H from the wire HI, which will then exhibit only a point. With this difference in the apparatus, repeat both the above experiments; and it will be found that the piece of wood ILMK is in neither case moved from its place, nor will any explosion occur. Thus we not only demonstrate the preference of pointed conductors over blunted ones for the preservation of houses, but also shew that a house furnished with sharp terminations, although not furnished with a regular conductor, is almost sufficiently guarded against the effects of lightning.

This apparatus is sometimes made in the shape of a house, as represented in fig. 2, where, to shew the interior, the side and part of the roof next the eye are not represented. The gable end AC represents that of the thunder-house, and may be used in the same manner as the above-described, or more readily by the following method: Let one ball of the discharging rod touch the ball of the charged jar, and the other the knob A of the conductor AC of the thunder-house; the jar will then of course explode, and the fluid will act upon the conductor just mentioned. The conducting wire at the windows *h h*, must be placed in a line. The sides and gable AC, of the house, are connected with the bottom by hinges: and the building is kept together by a ridge on the roof. This model may also be used by filling the brass tube *a* with gunpowder, and ramming the wire *c* a little way into it at the side; then connecting the wire *c* with the bottom of a large jar or battery. When the jar is charged, form a communication from the wire *c*, to the top of the jar, by the discharging rod: the discharge will fire the powder, and the explosion of the latter will throw off the roof, with the sides,

back, and front, so that they will all fall together. The figures *f* and *g*, at the side of the house represent a small ramrod for the tube *a*, and a pricker for the touch-hole at *c*.

Fig. 3 represents a mahogany pyramid, by means of which the same experiment may be performed. The piece at *a* being thrown out by the discharge, the upper part falls down in three pieces.

To illuminate Eggs, Ivory, Boxwood, &c

Fig. 4 represents a small mahogany stand, so constructed as to hold three eggs at a greater or smaller distance, according to the position of the sliding pieces. A chain C is placed at the bottom in such a manner as to touch the lower part of the egg at B with one end, and with its other end the outside coating of a charged jar. The sliding wire A, at the top, is made to touch the upper egg; and the distance of the eggs asunder should not exceed the quarter or eighth part of an inch. The electricity being, by means of the discharging rod, sent down the ball and wire at A, will in a darkened room render the eggs beautifully luminous and transparent.

To illuminate ivory, place a ball of this material on the prime conductor of the machine, and take a strong spark, or send the charge of a jar through its centre, and it will be rendered perfectly luminous; but if the charge be not taken through the centre, it will pass over the surface of the ball and stain it. A spark taken through box-wood, not only illuminates the whole, but makes it appear of a beautiful crimson or scarlet colour.

Gold leaf and Dutch metal may be rendered luminous by discharging the contents of a small Leyden jar over them. A strip of gold leaf, one-eighth of an inch in breadth and a yard long, will frequently be illuminated throughout its whole extent, by the explosion of a jar containing two gallons. This experiment may be pleasingly diversified, by laying the metallic leaf on a piece of glass, and then placing the glass in water; for the whole of the gold leaf will appear most brilliantly luminous in the water, by exposing it, thus circumstanced, to the explosion of a battery.

To illuminate Water.

Connect one end of a chain with the outside of a charged jar, and let the other end lie upon the table. Place the end of another piece of chain at the distance of about one quarter of an inch from the former; then set a decanter of water upon these separated ends, and on making the discharge, the water will be illuminated.

The electrified capillary Siphon.

Let a small bucket of metal filled with water be suspended from the prime conductor, and put into it a glass siphon so narrow in the extremity that the water may but just drop from it. If in this disposition of the apparatus, the winch of the machine be turned, the water, which, when not electrified, ran out only by drops, will now run in a full stream, or even be subdivided into smaller streams; and if the experiment be made in the dark, the appearance will be exceedingly beautiful. The same appearance will be exhibited by a smaller bucket with a jet, as shewn at fig. 5, pl. III, or the experiment may be agreeably varied by hanging one bucket from a positive conductor, and another from a negative one, so that the ends of the tubes or jets may be about three or four inches from each other. The stream issuing from the one will be attracted by that issuing from the other, and both will unite into one; but though both are luminous in the dark previous to their conjunction, the united streams will not be luminous unless the electricity of the one is stronger than that of the other.

To fire Gunpowder.

Take a small cartridge of paper, or the tube of a quill, and fill either of them with gunpowder; in each end of the cartridge or quill insert a wire, and let the extremities of the wire be about the fifth of an inch from each other. Then send the charge of a jar through the wire, and the gunpowder will take fire. If the gunpowder be mixed with steel filings, it may be fired by a less shock than would otherwise be required.

If gunpowder be placed loosely upon a stand, and the interruption of the wire circuit be in other respects the same, on discharging the jar, the spark will merely scatter without firing it; but even in its loose state, the gunpowder will be fired, if the discharge be made through imperfect conductors. For this reason, water is commonly made part of the circuit, and the electric fluid then strikes the gunpowder with more force. The experiment may be conducted thus: a glass tube, (suppose eight or ten inches long) filled with water, must be corked at each extremity; through one cork, so as to reach a very little way within the water, is inserted the wire communicating with the inside of the jar, through the other cork is inserted another wire, also just reaching into the water, and projecting a little externally above the cork. The jar being placed upon a table on which some gunpowder is laid, and the glass tube held vertically at a little distance from the jar, with its

lower wire among the gunpowder, on making the discharge, the electric fluid has to pass to the outside of the jar through the water and along the table, and the water and table being both imperfect conductors, the gunpowder lying between them is fired by the force of the stream.

To melt Wires

To melt wire by means of electricity, the wire should be attached by one end to the hook communicating with the inside coating of a battery, and the other end fastened to one limb of the discharging rod; then when the battery is charged, the circuit may be completed with safety and convenience. Thirty square feet of coated surface will fuse the greater part of two feet of wire one-fifth of an inch in diameter. If the power of the battery be very considerable, the melted metal will be dispersed and totally lost.

If a wire be kept stretched, while it receives a shock just sufficient to make it red-hot, it will be lengthened by the operation; but when the wire is not stretched, and the power of the battery is insufficient for its fusion, it is often shortened by the explosion. Van Marum shortened a wire, eighteen inches long, and one fifty-third of an inch in diameter, a quarter of an inch at a single discharge.

The facility with which metals are fused by electricity is not the same as that of their fusibility by fire. Van Marum caused wires of different metals to be drawn through the same hole, of one thirty-eighth of an inch in diameter, and observed how many inches of each could be melted by the explosion of his battery, which contained 225 feet of coated surface; taking care, in all these experiments, to charge it to the same degree, as ascertained by his electrometer. The results were as follow:

		inches.				
Of Lead	the discharge	melted 120;	the same metal melts	by fire	at 612	Fah.
Tin	..	120	..	..	442	..
Iron	..	5	..	..	21637	..
Gold	..	3½	..	..	5237	..
Silver	..	not quite 0½	..	[illegible]	4717	..
Copper	..	do.	..	..	4587	..
Brass	..	do.	..	..	3807	..

The artificial Earthquake.

Van Marum, with the battery above mentioned, in order to imitate the phenomena of earthquakes, followed Dr. Priestley's method of making the electrical explosion pass over a board, floating on water, on which several columns of wood were

erected; but this succeeded only once. Reflecting that the electric explosion exerts the greatest lateral force when it passes through imperfect conductors, and that water is probably its principal subterraneau conductor, he laid two smooth boards upon each other, moistening with water the sides which were in contact; upon the uppermost he placed pieces of wood, in imitation of buildings, the bases of which were three inches long, and 1½ broad. When the charge of the battery was transmitted between the boards, all these were thrown down by the tremulous and undulatory motion of the board on which they stood.

To prove that Glass and other Electrics become Conductors when very hot.

In order to ascertain the conducting quality of hot resinous substances, oils, &c. bend a glass tube in the form of an arch, CD, fig. 6, pl. III, and tie a silk string CGD to it, which will serve to hold it by when it is set near the fire; fill the middle part of this tube with rosin, sealing-wax, &c. then introduce two wires, *a a*, through its ends, so that they may touch the rosin, or penetrate a little way into it. Now let a person hold the tube over a clear fire, which will in a short time melt the rosin it contains; but before the melting takes place, connect one of the wires *a a* with the outside of a charged jar, and touch the other with the knob of the jar, with a view to make the discharge through the rosin, and it will be found, that while the rosin is cold, no shocks can be transmitted through it: but it becomes a conductor as it melts, and when wholly melted, the shocks will pass through it very freely.

To shew that the Electric Fluid prefers a short passage through the Air, to a long one through good Conductors.

Bend a wire about ten feet long, at the ends of which fix a piece of glass G, fig. 7, to keep the knobs AB at a proper distance, so that they may slide within half an inch of one another, if required; then connect one of the chains belonging to the sliding wires with the hook of the battery, and the other with the discharging rod, and send the charge of a battery through the bent wire. On making the explosion, a spark will be seen between A and B, which shews that the electric fluid chuses a short passage through the air rather than a long one through the wire. The charge, however, does not pass entirely through A and B, but part of it also goes through the wire, which may be proved by putting a slender wire between A and B; for on making the discharge, with only this difference in the apparatus,

the small wire will scarcely be made red-hot, whereas if the large wire ADB be cut in D, so as to discontinue the circuit ADB, the small wire will be melted, and even exploded by the same shock that before made it scarcely red-hot.

In this manner the conducting power of different metals may be tried, using metallic circuits of the same length and thickness, and observing the length of the passage through the air with each.

To prove that the Electric Fluid displaces and rarefies the Air.

The electric thermometer enables us to observe the effects of the electric explosion upon air. The body of this thermometer consists of a glass tube A, fig. 8, about ten inches long, and nearly two inches in diameter, and closed air-tight at both ends by two brass caps. Through a tube H of very small bore, is introduced some water, to the bottom of the large tube. Through the middle of each of the brass caps, a wire is introduced, having a brass knob within the glass tube, and by sliding through the caps they may be set at any distance from each other. This instrument is, by a brass ring C, fastened to the glass pillar, F, of a wooden stand.

When the air within the tube A is rarefied, it will press upon the water at the bottom of the tube, which will consequently rise in the cavity of the small tube; and as this water rises higher or lower, so it shews the greater or less rarefaction of the air within the tube A, which has no communication with the external air.

If the water, when this instrument is to be used, is all at the bottom of the large tube, that is, if none of it be in the cavity of the small tube, it will be proper to add an additional quantity of that fluid, and thus cause it to rise a little in the small tube, on which, to ascertain the change produced in the experiment, a mark may be fixed.

Bring the knobs of the wires IK into contact with one another, then connect the ring of I or K with one side of the charged jar, and the other ring with the other side, by which operation a shock will be made to pass through the wires IK, that is, between the knobs of those wires. In this case, the water in the small tube will not be moved from the mark; which shews that the passage of the electric fluid, through conductors sufficiently large, occasions no rarefaction, nor displaces the air about them.

Put the knobs a little distant from each other, and send a shock through them as before, and the spark between the two knobs will not only displace the air, but rarefy it considerably;

for the water will be suddenly pushed up in the small tube, and immediately it will subside a little, for instance, as far as H; which is occasioned by the sudden displacing of the air about the place where the spark appeared within the tube A. After the water has subsided suddenly from the first rising, it will gradually and slowly come down to the mark at which it stood before the explosion; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room where the degree of heat is variable, then proper allowance must be made for this circumstance, in estimating the event of the experiment: for the electrical air thermometer is of course affected by heat or cold in general, as well as by the electric spark.

Magnetism produced by Electricity.

Dr. Van Marum, by the grand electrical battery before mentioned, tried to communicate magnetism to needles made out of watch-springs of three and even six inches in length; as well as to steel bars nine inches long, from a quarter to half an inch in breadth, and about a twelfth part of an inch in thickness. The result was, that when the bar or needle was placed horizontally in the magnetic meridian, which ever way the shock entered, the end of the bar that stood towards the north acquired the north polarity, and the opposite end acquired the south.

If the bar, before it received the shock, had some polarity, and was placed with its poles contrary to the usual direction, then its natural polarity was always diminished, and often reversed; so that the extremity of it, which in receiving the shock was directed towards the north, became the north pole, &c. When the bar or needle was struck while standing perpendicularly, its lowest end always became the north pole, even when it had some magnetism before, and was placed with the south pole downwards. All other circumstances being alike, the bars seemed to acquire an equal degree of magnetic power, whether they were struck while disposed horizontally in the magnetic meridian, or perpendicular to the horizon. When a bar or needle was placed in the magnetic equator, the entrance of the shock at either end never gave it any magnetism; but if the shock was given through its width, then the needle acquired a considerable degree of magnetism, and the end which lay towards the west became the north pole, and the other end the south pole.

If a needle or bar, already magnetic, or a real magnet, was struck in any direction, its power was always diminished. For

this experiment considerable bars were tried; one being 7.08 inches long, 0.26 broad, and 0.05 thick. When the shock was so strong, in proportion to the size of the needle, as to render it hot, then the needle generally acquired either no magnetism at all, or very little.

The Electrophorus.

If an insulated brass plate be brought into contact with an insulated cake of resin, which has been excited by rubbing it with a silk handkerchief, it will afford strong signs of electricity, and even give a spark. The instrument constructed to shew this, is called an *electrophorus.* It was invented by Professor Volta, an Italian. The plates of which it consists may be in any form, but they are generally made circular, as AB, fig. 9, pl. III. They are used of all sizes, from six to eighteen or twenty inches; but if the larger of them be twelve inches, it will unite convenience and power in a higher degree than any size materially greater or less. The lower plate B consists of the electric, which is generally some resinous composition that will bear rubbing without producing any disagreeable adhesion. The upper plate A is nearly the same size as the lower B, and is made of some conducting substance, generally of brass, but wood covered with tin-foil will answer, and may, from its lightness, be more suitable when the instrument is intended to be so large that metal would be too heavy for one hand to lift. In the centre, from the upper side of this plate, rises a glass handle, by which, it is obvious, the plate may be lifted up, and still remain insulated.

This machine is used in the following manner: the plates being separated, the upper surface of the electric B, which may be placed either upon an insulating stand as in the figure, or on a table, is rubbed with a piece of clean new flannel or silk, which will produce negative electricity on the electric, and when it is excited as much as possible, the metallic or conducting plate A is placed upon it. On touching the metallic plate, in this situation, with a finger or any other conductor, a spark is obtained. On taking up the metallic plate by its glass handle, and trying it separately, it will be found possessed of an electricity contrary to that of the electric, viz. positive, and will give a strong spark to any conductor brought near it. When the electricity of the metallic plate is drawn off, it may be renewed by again placing it in contact with the cake of resin, without the re-excitation of the latter. The second spark afforded by the metallic plate will be apparently as strong as the first; and the same remark applies to a great number of suc-

cessive trials. If at each separation of the plates, the knob of a coated jar be held to the metallic one, the jar will soon become as fully charged, as if it had been applied to a prime conductor.

The following composition has been recommended for the lower plate of the electrophorus: four parts rosin, three parts pitch, three parts shell-lac, and two parts Venice turpentine, melted together over a gentle fire. This mixture may be poured out and spread upon a thin linen-cloth, till it lies about a quarter of an inch thick. The linen cloth must be stretched upon a hoop, and made as tight as possible. If the surface be somewhat rough, it will be rather more than less effectual. Shell-lac, very slowly dissolved with a little Venice turpentine, will form a good plate for the purpose without any further addition. It must be observed, however, that, after many trials, Cavallo found that plates the strongest in power, as well as the easiest to construct, were made with the second sort of sealing-wax, spread upon a thick plate of glass. This kind of sealing-wax is composed of shell-lac and rosin, coloured by vermilion or red lead;—(See the recipe, among the Miscellanies at the end of this vol.) A plate which Cavallo made of this substance, though no more than six inches in diameter, when once excited, would charge a coated jar several times successively, so strongly as to pierce a hole through a card with the discharge. Sometimes the metal plate, when separated from it, darted strong flashes to the table upon which the electric plate was laid, and even into the air, besides causing the sensation of the spider's web upon the face brought near it, like an electric strongly excited. Cavallo also observes, that the power of some of these plates is so strong, that the electric plate adheres to the metal, when the latter is lifted up, nor will they separate even if the metal plate is touched with the finger or other conductor. Sometimes the electric will not act well at first, but is rendered very good by scraping with the edge of a knife the shining or glossy surface of the wax.

The durability of the electricity communicated to the electrophorus is very remarkable; it will sometimes continue as long as three weeks, without being rubbed again, but it must be admitted, that the act of placing the metallic plate upon it, and suddenly plucking it off, operates in some measure like friction to the revival of its electricity.

Of the wide Diffusion of Electricity.

The electrometer and other instruments which have been adopted to indicate small quantities of electricity, enable us to discover that electricity may be obtained in a great number of ways as well as by friction, insomuch that we have reason to consider this power as a universal agent of nature. 1. It is produced by the heating or cooling of a variety of substances; 2. by the evaporation and condensation of vapour; 3. by the natural changes in the atmosphere; 4. by the will of certain animals; and 5. by the action of certain bodies on each other when in contact.

The investigation of the effects and nature of the electricity produced by the action of conducting bodies when in contact upon each other, has furnished philosophy with such a vast variety of interesting facts and speculations, that this branch of electricity has been erected into a new science, under the appellation of *galvanism;* and we shall accordingly treat of it separately. It is only then the other four sources of electricity which we shall now advert to in their order, commencing with

The Electricity evolved in the heating and cooling of various Substances.

This electricity has been sometimes called *spontaneous* electricity. It was discovered by Wilcke in the instance of sulphur. If sulphur be melted in an earthen vessel, and then left to cool in the same vessel upon conductors, it will, upon being taken out of the vessel after it is cold, be found strongly electrical; but if left to cool upon electrics, no such effect ensues.

If sulphur be melted in a glass vessel, and left to cool, both the glass and the sulphur acquire a strong electricity, whether placed upon electrics or not; but the electricity is stronger when they are cooled upon electrics than when cooled upon conductors: and if the glass vessel be coated with metal, the electricity acquired is strongest of all. In these cases, the glass is always positive, and the sulphur negative.

Melted sealing-wax poured into glass acquires a negative electricity; but if poured into sulphur, its electricity is positive, and that of the sulphur negative. Sealing-wax poured into wood is negative, and the wood positive; but sulphur poured into sulphur, or into rough glass, acquires no electricity whatever.

If melted sulphur be poured into a metal cup, and there left to cool, the sulphur and cup will shew no signs of electricity while together; but the moment they are separated, they appear to be strongly electrified. On replacing the sulphur, the elec

tricity disappears, but is again revived on taking it out. The electricity of the cup is negative; that of the sulphur positive. If, when the cup and sulphur are separated, the electricity of either substance be taken off, they will, when united, shew signs of that electricity which has not been taken off.

Many other substances, as well as the above-mentioned, betray similar signs of electricity; thus chocolate, fresh from the mill, as it cools in the tin pans in which it is received, becomes strongly electrical, and continues so for some time; and after having lost this property, it may be renewed by re-melting it, unless rendered very dry in this operation.

Among those substances which evince their electrical properties by change of temperature, the most remarkable is the *tourmalin*, which is a precious stone of the flint kind, found in Ceylon, the Brazils, and Siberia. It is in some degree transparent, and of different colours—sometimes red, sometimes brown, purple, or green; its size seldom exceeds that of a walnut. Cavalio has enumerated the electrical properties of the tourmalin, in the following manner:

"1. The tourmalin, while kept in the same temperature, shews no signs of electricity; but it will become electrical by increasing or diminishing its heat, and stronger in the latter circumstance than in the former. A very trifling alteration of temperature is often sufficient to produce the effect.

"2. Its electricity does not appear all over its surface, but only on two opposite sides of it, which may be called its poles, and which always are in one right line with the centre of the stone, and in the direction of its strata; in which direction the stone is absolutely opake, though in the other it is semi-transparent.

"3. While the tourmalin is heating, one of its sides (call it A) is electrified plus or positive, and the other, B, minus; but when cooling, A is minus, and B is plus. Hence, if one side of the stone is heating, whilst the other is cooling, then both sides will acquire the same electricity; or if one side only changes its temperature, then that side only will appear electrified.

"4. If this stone be heated, and suffered to cool, without either of its sides being touched, then A will appear positive, and B negative, all the time of its heating and cooling.

"5. This stone may be excited by means of friction, like any other electric, and either of its sides, or both, may be rendered positive.

"6. If the tourmalin be heated or cooled upon some other insulated body, that body will be found electrified as well as the stone; but it will be found possessed of the electricity contrary to that of the contiguous side of the stone.

"7. The electricity of either side, or of both, may be reversed by heating or cooling the tourmalin in contact with various substances, such as the palm of the hand, a piece of metal, &c.

"8. These properties of the tourmalin are also observable in vacuo, but not so strong as in the open air.

"9. If a tourmalin be cut into several parts, each piece will have its positive and negative poles, corresponding to the positive and negative sides of the original stone.

"10. If this stone be covered all over with some electric substance, such as sealing-wax, oil, &c. it will in general shew the same properties as without it.

"11. A vivid light appears upon the tourmalin, whilst heating in the dark, and by a little attention one may be easily enabled by this light to distinguish which side of the stone is positive, and which negative. Sometimes, when the stone is strongly excited, pretty strong flashes may be seen in the dark, to go from the positive to the negative side of it.

"12. It has been found, that with respect to the electric properties, the tourmalin is sometimes injured by the action of a strong fire, at other times is improved, and sometimes is not at all altered by it."

The more transparent the tourmalin, the stronger are its electrical effects. It may also be observed, that many other precious stones, particularly the transparent ones, exhibit electrical properties of a similar nature; but the tourmalin is selected for exemplification, because it is the most remarkable.

Of the Electricity evolved in Evaporation and the Condensation of Vapour.

Volta discovered that bodies from which water had evaporated shewed signs of negative electricity, by which it appears that water, in the state of vapour, retains a larger portion of the electric fluid than in the state of water. Exceptions have, however, been discovered to this rule: 1. If water be evaporated by contact with a red-hot piece of rusty iron, it will leave the iron electrified positively; but the iron will be negatively electrified if not rusty. 2. If water be evaporated by throwing into it impure red-hot glass, (such as the green glass of common bottles,) the vessel or the remaining water will be electrified positively.

To prove the effects of evaporation in exciting electricity, place a metallic cup, containing water, upon the cap of Cavallo's electrometer, then upon dropping a red-hot coal into the water, the instantaneous evaporation that follows, will cause the balls

to diverge with negative electricity. The converson of any other fluid into vapour produces the same effect as water.

As the capacity of water for electiicity is increased by its conversion into vapour, it will obviously be inferred, that the condensation of vapour will cause the electricity which then becomes superabundant to be given out to any conductor that happens to be sufficiently near. Accordingly it is found, that an insulated metallic plate held in a volume of steam, is electiified positively by the condensation and conversion into wa ter of the vapour striking upon its surface.

Atmospheric Electricity.

Since Franklin and his contemporaries first drew lightning from the clouds, and exhibited with it the whole series of electrical phenomena, no experiment has ever been devised, which could throw a shadow of doubt on the identity of lightning and electricity. Accordingly, lightning is only to be considered as a name for a vast accumulation of electricity; or electricity as a name for small quantities of lightning. When we consider the pungency of a spark supplied by a few inches of glass, we cannot hesitate to allow that the effect of the spark drawn from a thousand acres of electrified cloud must be violent in the extreme.

The atmosphere almost at all times affords signs of electricity, and before we proceed further with this subject it will be proper to advert to the means commonly used to discover it. Cavallo's electrometer, as already observed, is a very useful instrument for this purpose. By holding it up a few feet above the ground, the pith-balls will generally diverge, and the kind of electricity may be ascertained by touching it with any excited electric in the manner already described, observing that the electricity of the instrument in this case, is the contrary of that of the atmosphere; but if the electrometer be electrified by rain, hail, or snow falling upon it, its electricity is the same as that of the rain, &c.

When the electricity of the atmosphere is at too great a distance, or too slight to affect an electrometer held in the hand of a person on the ground, the instrument may be carried to the top of a house, or an electrometer may be contrived that may be pushed out to a distance; for example, from an upper room window. For this purpose, Cavallo makes use of a slender rod like those used for fishing. The extremity of this rod terminates in a tube or rod of glass coated with wax, in order to insulate two small cork balls suspended from the end of it by hempen threads. Upon the end of the glass tube is put a

cork, from which the electrometer is suspended. In this situation the electrometer is insulated, but to take away its insulation until it is pushed out to its proper place, a pin is stuck into the cork at the end of the glass tube, and to this pin is affixed a packthread which reaches to the lower end of the wooden rod held in the hand. When this instrument is pushed out of a window, which may be done in an angle of 50° or 60° with the horizon, the packthread is drawn in to disengage the pin stuck into the cork, and the balls of the electrometer are then left insulated, and therefore acquire the electricity of the atmosphere, and may be drawn into the room and examined with convenience.

Instruments have been invented, called multipliers or doublers of electricity, intended to be used where extreme delicacy of examination is proposed; but the action of these is rather of a dubious nature, and we shall therefore proceed to the notice of the *electrical kite*.

The kite used by electricians differs in no respect from those used among children, except that the paper is covered with drying linseed-oil, to prevent its being destroyed by rain, and a slender wire is interwoven with the string to render it a better conductor. It is, however, doubtless known to almost every one, that there is a considerable difference among children's kites in their flying properties: some of them, under every favourable circumstance of wind and size, can scarcely be raised or kept aloft by any exertion, so that the pertinacity of infantine perseverance, in affairs of sport, is almost exhausted in attending to them. We shall therefore give the proportions which will certainly answer well, and as these may be observed with so much facility, we presume it will not be required that we should devote a sentence to the consideration of how much they may be deviated from without hazarding the convenience of raising the machine. The straighter AB, fig. 10, pl. III, and the bow CAD, should, when the latter is open, be of the same length, reckoning the length of the straighter from the place where it is notched to the bow. By this means, when the bow is in its place, the cord CD, which connects its extremities, passes over the straighter at the distance of one-third of the length of the latter from its end A; and the tapering of the kite therefore commences at two-thirds of its length from its pointed extremity. The cord to which the cord for raising the kite is attached, is fastened by both ends to the straighter, one end at *d*, one-sixth of the whole length of the kite from the end A; and the other at *f*, one-third of the whole length of the kite from the extremity B. The length of the cord

d e f, may be about equal to that of the straighter. The cord *e g*, the length of which regulates the distance of the flight of the kite, must be attached to such a part of the cord *d e f*, that the kite, if suspended by it, when without a tail, shall remain horizontal, that is, it shall be just opposite the centre of gravity of the kite; and if the weight of paper on each side of the straighter is not equal, it should be made so by putting on additional pieces. The tail of the kite should be seven times the length of the straighter, and it should be loaded in about twenty different places, with some such material as rolls of paper, and a bob or heavy roll of the same kind at the end of it. The proper weight of the tail is easily ascertained by a few trials. The straighter should he made of fir, and the bow cannot be made of any thing better than a light hoop. A kite thus constructed will easily be raised with a moderate wind to a great height. If the paper be oiled after the kite is finished and dry, which is perhaps the best way, it should be damped with a sponge and water before it is pasted, in order that it may dry without wrinkles. A kite four feet high is found very convenient for electrical purposes.

In an electrical point of view, according to Cavallo's experiments, the whole power of the kite consists in the string; it is therefore of little use to coat the straighter with tin-foil, or tip it with iron as some have proposed; but it is important to make the string a good conductor. For this purpose the simplest mode is to wet it; but it is better still, to use, with two threads of common hemp, one of the copper thread used for trimmings.

The highest idea which the ancients could form of omnipotence, comprised the exclusive ability of directing the thunderbolt; the power of which they considered to be absolutely irresistible, and the command of it immeasurably removed from human control. If then we venture to interfere with this astonishing agent of nature, let us remember its tremendous power, and not for a moment forego the precautions that will ensure safety. In serene weather there is never any danger in raising the kite; but it is always unsafe to raise it during a thunder-storm, or while black clouds are hovering over head; for the quantity of electricity brought down will often be very great, although there may be no thunder. When the electricity, therefore, during a storm, is intended to be observed, the kite should be raised while the air is yet tolerably clear: at the lower end of the conducting line should be attached three or four yards of silk cord covered with wax, that it may not, by getting damp, readily become a conductor. From the termination or some other part of the conducting line, a chain

of sufficient length to reach to the earth should be fastened; or instead of it, when jars are to be charged, and other experiments are to be made, a slender wire may reach from the conducting line to an insulated prime conductor. This conductor should be furnished with a quadrant electrometer, that the strength of the electricity may be determined by inspection. The wire connecting the string of the kite and the prime conductor should not be stretched, to prevent the motions of the string or conducting line from throwing down the conductor. In making experiments with an insulated string, especially when a storm is apprehended or actually present, it would be proper to have a rod of iron or some other good conductor in direct communication with the earth, and within an inch or two of the string, so that notice would be given of the descent of any unusual quantity of electricity by the snapping between this conductor and the string, and the operator would have time to provide for his safety.

Cavallo made a great number of experiments with the electrical kite, and his conclusions are drawn up in the following manner:

"1. The air appears to be electrified at all times; its electricity is constantly positive, and much stronger in frosty than in warm weather; but it is by no means less in the night than in the day-time.

"2. The presence of the clouds generally lessens the electricity of the kite; sometimes it has no effect upon it, and it is very seldom that it increases it a little." Cavallo himself relates a remarkable exception to this rule which occurred to himself, and in which he was nearly overpowered by the shocks he received from the accidental presence of a cloud; but perhaps he here means the light clouds of fine weather.

"3. When it rains, the electricity of the kite is generally negative, and very seldom positive.

"4. The aurora borealis seems not to affect the electricity of the kite." Others have observed the contrary of this.

"5. The electric spark taken from the string of a kite, or from any insulated conductor connected with it, especially when it does not rain, is very seldom longer than a quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the person that takes the spark will feel the effect of it in his legs; it appearing more like the discharge of an electric jar than the spark taken from the prime conductor of an electrical machine.

"6. The electricity of the kite is generally stronger or weaker, according as the string is longer or shorter; but it does not keep any exact proportion to it. The electricity, for

instance, brought down by a string of a hundred yards, may raise the index of the electrometer to twenty, when, with double the length of string, the index of the electrometer will not go higher than twenty-five.

"7. When the weather is damp, and the electricity is pretty strong, the index of the electrometer, after taking a spark from the string, or presenting the knob of a coated phial to it, rises surprisingly quick to its usual place; but in dry and warm weather it rises exceedingly slow."

It may be inquired how the vast quantity of electricity developed in thunder-storms is produced. To this an answer may be derived from the preceding section, in which we have seen that vapour contains in almost all cases a greater quantity of the electric fluid than the water from which it is formed. A cloud or collection of vapours, therefore, will by condensation become strongly plus, and by rarefaction will become minus; and if two clouds in these opposite states approach near each other, a discharge will ensue to restore the equilibrium; the discharge will be attended with a flash, constituting the lightning, and the lightning dividing the air and forming a vacuum by its velocity, the divided air, on rushing together again, produces the thunder. The very same cause produces the snapping of the slightest spark. It may also be observed, that the phenomena of thunder and lightning will ensue when a cloud, either plus or minus, strikes the earth, instead of another cloud.

After experiments with the electrical kite and elevated conductors had proved that lightning could be drawn from the clouds in immense quantity, it ceased to be a doubtful question whether buildings might not be rescued from the hazard of destruction by lightning, if they were furnished with conductors, reaching above the most elevated part of them, and having an unbroken connection with the earth. But while the usefulness of conductors for this purpose appeared indisputable, a controversy arose as to the best form for them. It was maintained by one party, that they should have blunt terminations; by another, that they should be pointed. Pointed conductors, it was argued, would attract distant electricity that would not affect blunt ones; but it was replied, that they would attract and carry it off in an innoxious stream, at all distances where it had any effect; while the discharge to a blunt conductor would often be vehement and destructive. In the end, a number of experiments, made under the inspection of the Royal Society, decided the question in favour of pointed conductors, and no other are now in use.

An effective conductor should rise eight or ten feet above the highest part of the edifice it is intended to secure, and

should terminate in several short branches, each of which must be pointed, in order that if one or more be melted by the lightning, the rest may perform the duty assigned them. It should not be smaller than half or three-quarters of an inch in diameter, and as its effects would be injured by rust, which is a non-conductor like oxides in general, the upper part of it should be copper, or if of iron, it should be plated with gold or platina. When not composed of one single piece of metal, the several joinings should be very close. The conductor should not descend very close to the side of the house, particularly if it contain combustible materials, and care should be taken to direct it from the house towards the foundation, and terminate it if possible in moist earth or water several feet under ground. It should also be fastened to the house by wooden holdfasts, when it cannot be conveniently detached altogether.

Small buildings may be considered sufficiently guarded by a single conductor, but large ones will require more. In general it may be calculated that a single conductor secures a space of ten yards round it.

A conductor of lead must be four times the diameter of an iron one to afford the same security; but copper need be only half the diameter of iron to effect the same purpose. Square iron rods of half an inch in thickness, will withstand the strongest lightning.

The propriety of securing ships is not less obvious than that of securing buildings, and a chain has been generally used, connected with a rod rising some feet above the main-mast; but the quantity of electricity brought down is often so great, that the obstruction to its course between the links often snaps the chain. It is therefore better to use a copper-wire accommodated to the vessel by bending, and terminating in the water.

It has sometimes happened, in America especially, where thunder-storms are more sudden and more violent than with us, that edifices have been struck by lightning, although furnished with metallic conductors. On this account, the American Philosopical Society adjudged to Robert Paterson a gold medal, for his essay on the improvement of conductors. Paterson proposes, first, to insert on the top of the rod a piece of the best black-lead, about two inches long, and terminating in a fine point, which must project a little above the end of the point of the rod; so that if the black-lead point should, by any accident, be broken off, that of the rod would be left sharp enough to answer the purpose of a metallic conductor. His second intention is, to facilitate the passage of the electric fluid from the lower part of the rod into the surrounding earth.

In many cases it is impracticable, from the interruption of rocks and other obstacles, to sink the rod so deeply as to reach moist earth, or any other substance which is a tolerably good conductor of electricity. To remedy this defect, he proposes to make the lower part of the rod either of tin or copper, which metals are far less liable to corrosion or rust than iron, when lying under-ground; or, which will answer the purpose still better, to coat that part of the conductor, of whatever metal it may consist, with a thick crust of black-lead previously formed into a paste, by being pulverized, mixed with melted sulphur, and applied to the rod while hot. By this precaution, the lower part of the rod will, in his opinion, retain its conducting power for ages, without diminution. In order to increase the surface of the subterraneous part of the conductor, he directs a hole or pit, of sufficient extent, to be dug as deep as convenient, into which should be put a quantity of charcoal, surrounding the lower extremity of the rod. Thus the surface of that part of the conductor which is in contact with the earth, may be increased with little trouble or expense; a circumstance of the first importance to the security against those accidents, as charcoal is generally an excellent conductor, and not subject to change its properties. It is necessary, however, to ascertain that the parcel of charcoal used is a good conductor, as all kinds are not of that character. With respect to the black-lead, directed to be used at the top of the conductor, it may be doubted whether any service would be rendered by it; it is recommended by the proposer of it, because lightning will not fuse it, but Dr. Van Marum found that the discharge of his battery always reduced the strongest black-lead to powder; and therefore it must be supposed that the effect of lightning will not be inferior.

Personal security, during a thunder-storm, forms another object of important consideration. Dr. Franklin advises persons apprehensive of lightning to sit in the middle of the room, not under a metal lustre, or any other conductor, and to lay their feet on another chair. A precaution of this kind is the easiest that can be observed, and ensures a high degree of safety; but the Doctor adds, for the information of those whose timidity induces them to purchase relief from their fears at any price, that it will be still safer, to lay two or three beds or mattrasses in the middle of the room, and folding them double, to place the chairs upon them. A hammock, suspended by silken cords, would be an improvement even upon this apparatus. The floor should be dry, or the lightning, if it strike the house, will fly over it. As the walls and floors

of houses are usually dry, and therefore bad conductors, the lightning is prevented from spreading, and often seizes with so much the more avidity the slightest articles of metal in its way. A person lost his life by happening to be leaning with his head near the bell-wire of an apartment where the lightning had entered; and even the electricity conducted by the gilding of a picture-frame, might produce an equally fatal catastrophe. Dr. Priestley observes, that the place of most perfect safety, is the cellar, and especially the middle of it; for when a person is lower than the surface of the earth, the lightning must strike it before it can possibly reach him. It is therefore most probable that it will become immediately diffused, and not enter the cellar, especially if it be not damp.

The best situation for a person who happens to be in the fields during a thunder-storm, is, not immediately under, but within a short distance of a tree; as the lightning generally strikes first the highest and best conductors.

Lord Stanhope observes, that damage may be done by lightning, not only by the main stroke, but by that which he calls the *returning stroke*, by which is meant the sudden and violent return of that part of the natural share of electricity which had been gradually expelled from some body or bodies, by the superinduced elastic, electrical pressure of a thunder-cloud. By this theory he solves some cases, otherwise of difficult explication.

When the identity of lightning and electricity had been cleared of all doubt, philosophers were induced to suppose that electricity might be the agent in many other atmospherical phenomena. The aurora borealis, streamers, or northern lights, was particularly singled out as an electrical appearance, and it appeared to strengthen the conjecture, that this phenomenon can be admirably imitated, in the manner already stated, by a conductor, or glass vessel exhausted of air. That the aurora borealis takes place at very great heights, is obvious from their being seen in distant countries at the same time. Dalton has estimated the height of the rainbow-like arches formed by it at 150 miles, but other appearances of the kind have been estimated at 400, 600, 800, &c. miles. At the lowest of these heights, the rarity of the air will be not unlike that of an ordinary vacuum, and the electric fluid, if existing at such a height, would doubtless diffuse itself as in such an approximated vacuum. The aurora borealis affects the magnetic needle, which is another reason why it is probably an electrical phenomenon; and at the time it prevails, greater quantities of electricity are occasionally derived from the

atmosphere than at other times. The height at which the phenomenon occurs may prevent this electrical effect on the atmosphere from been common. No cause has, however, yet been assigned for the disturbance of the electric fluid in the higher regions, so as to produce light, nor why the appearance in question should be more common and intense the nearer we approach the poles, while at the equator it is never seen. The rustling, crackling noise is frequently heard to accompany the aurora borealis in England, or even in a lower latitude, but in regions ten or twenty degrees nearer the pole, its noise is like that of the largest fire-works playing off, and in Siberia is denoted by an expression equivalent to "the raging host is passing." The aurora borealis is seen most frequently after a dry summer, in frosty weather.

Those meteors, vulgarly called "falling stars," which may be observed, more or less frequently, almost any fine night, and some of which are remarkable for their splendour and the length of their course, are also supposed to have an electrical origin.

As water-spouts occur most frequently in those countries, and at those seasons of the year, when thunder-storms are most common, and lightning generally is seen either before or after them, their connection with electricity has been inferred, and their appearance explained on electrical principles. When the convergence of different winds has produced a whirling motion of the air, a strongly electrified cloud over the centre of the whirl, will easily attract the unelectrified water, and thus the cloud and the water will meet each other. It is some slight confirmation of the inference of electricity in these phenomena, that an electrometer shews strong signs of electricity during whirlwinds.

Electricity appears to connect the perturbations of earth and sky, in still more awful phenomena. Lightning is almost always observed in the discharge from a volcano, and during the time of an earthquake. Electricity gains force as it runs along a conductor, and often melts the extremity of a wire, while the remainder of it is unaffected: if, therefore, a large quantity of it, from a cloud, for example, finds a good conductor for a long course in the earth, and terminates at last among inflammable materials, the effects we see in volcanoes have an assignable cause perfectly adequate to their production. Earthquakes are often unattended with any vapour, smell, or fire; they are also often preceded or accompanied by the most terrific thunder-storms. As the earth is the grand reservoir of electricity, it is not hard to admit, that the

resistance which vast quantities of electricity may meet with, before an equilibrium takes place, may produce the undulatory motion which we call an earthquake. The earth, when dry, is a bad conductor, and will not receive the electricity from the clouds without a struggle. It is favourable to this hypothesis, that earthquakes in general affect only the outward surface of the earth, and seldom injure mines or springs; it is also worthy of remark, that earthquakes mostly take place in hot countries, where lightning and thunder most abound. Ships are affected in a manner that can scarcely be accounted for on the supposition that the commotion originates entirely within the earth; but if a person hold his hand in a quantity of water, through which the electrical shock is passed, he will receive a blow that will afford a tangible proof of what ships may feel in the electric shock of nature's operations.

Of Animal Electricity.

There are three species of fish which possess the power of giving an electrical shock; viz. the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*.

The torpedo has been known from the most ancient times, but the wonderful accounts given of its power, in part perhaps coloured in the narration, were till recently regarded as fabulous by those who had not witnessed them. It was not till the phenomena of electricity became familiar, and the coincidence between them and the power of the fish was clearly perceived, that they gained much credit. The torpedo is a flat fish, of the ray tribe, very seldom exceeding twenty inches in length, and twenty pounds in weight; though some have been occasionally caught that weighed from fifty to eighty pounds. It inhabits the Mediterranean and the North Seas. The electrical organs of this animal are two in number, and are placed on each side of the cranium and gills. Each organ consists of perpendicular columns, reaching from the under to the upper surface of the body, and varying in length according to the thickness of the fish in different parts. The number of these columns varies in different torpedoes, and also at different ages of the same animal. The length of each organ is somewhat less than one-third of the entire length of the fish. In a very large torpedo, one organ was found to consist of 1182 columns: the diameter of a column is generally about one-fifth of an inch.

If the torpedo, either in the water or out of it, but not insulated, be touched with one hand, it generally communicates a trembling motion, or slight shock, to the hand; but the sensation is felt in the fingers of that hand only. If the torpedo be touched with both hands at the same time, one being applied to its under, and the other to its upper surface, a shock will in that case be received, which is exactly like that given by the Leyden phial. The circuit may be composed of several persons joining hands, and the shock will be felt by them all at the same time. The shock of the torpedo is conducted by the same substances which conduct electricity, and is intercepted by the same bodies which are non-conductors of electricity.

The torpedo gives no shock when the hands are placed upon the electric organs of the same surface, which shews that the organ on one side is in the positive, and that on the other in the negative state, like the opposite surfaces of a jar. The shock which it gives when standing in air, is four times as strong as that which it gives when standing in water. There is a very perceptible difference in the strength of the shock occasioned by the length or diminution of its circuit. This is so remarkable, that it may be proved by a single person, for on taking the shock by touching the opposite organs with separate hands, and then taking it by touching the opposite organs with the finger and thumb of the same hand, the latter shock will be found much stronger than the former. The power of the torpedo sometimes produces only one single sensation of numbness in the hand: this is supposed to arise from a rapid succession of small shocks, which cannot be separately distinguished. In the space of a minute and a half, fifty strokes have been received from the animal, when insulated. This power appears to be entirely under the control of the animal, and is increased with any cause of irritation. It is also stated to be accompanied in every instance with a depression of the eyes. The animal commonly lies in forty-fathom water, and is supposed to stupify its prey by this singular faculty. It is sometimes imbedded in the sands of shallows, and is stated in these cases to give to those who happen to tread upon it, an astonishing and overwhelming shock.

The shock of the torpedo will not pass over the least interruption of continuity in a conductor; consequently no spark can be obtained from it. A plate of air not the 200th part of an inch thick, as between the links of a chain, is a barrier to its progress. This singularity is well accounted for by Walsh, who formed an artificial torpedo, by which the effects of the natural one were admirably imitated. He found that the same

quantity of electricity which, from a small jar, would give a smart spark, would, if diffused over a large jar, or over a battery of jars of the same size, scarcely give any spark or report, and its power of passing through a space of air is diminished in the same proportion, although the strength of the shock continues the same. The numerous columns in each electrical organ, then, he considers as so many separate vessels, each weakly charged, and consequently producing the same effect as a battery weakly charged. The artificial torpedo gave a considerable shock through a conductor, but an interruption of a hair's breadth stopped its course.

The next fish we have to notice as possessed of properties resembling the torpedo, is the *gymnotus electricus*, called also the *electrical eel*. This fish is generally of the length of three or four feet, is of an unpleasant appearance, much like a large eel, but thicker in proportion to its length, and always of a blackish brown colour. It has occasionally been seen of the length of ten feet. It is found in the hot climates of Africa and America, particularly in the rivers of Surinam and Senegal. Dr. Garden, of Charleston, South Carolina, after giving an elaborate description of the form and structure of this animal, adds, that it has the power of giving an electrical shock to any person, or to any number of persons who join hands together, the extreme person on each side touching the fish. There were five of these fishes under his immediate inspection at the above town, all of which possessed this property in a high degree, and they could communicate the shock, either immediately on being touched, or through the medium of a metalline rod; but when they were first caught, this power could be exerted by them with greater strength than afterwards. He observed that, in his own case, the shock was never experienced when the fish was laid hold of by him with one hand only; when it was held by both hands, at a considerable distance apart, he never failed to receive a sensible and smart shock. Indeed, if the fish be held by one hand, and the other hand be immersed in water immediately over its body, the same effect will follow as if it be held by both hands; and so it will be with respect to any number of persons joining in a circle, one hand of the person at one extremity holding the fish, and the other at the other extremity, placing his hand in the water over it. In Surinam river the electrical eel is caught considerably above the reach of the sea-water. It subsists on fishes, worms, or any animal food, which is small enough for it to swallow; and when any fish is sufficiently near, it immediately communicates to it a shock by which it is stupified. If the prey be large

several shocks are requisite, and are applied for this purpose, and many fish are thus destroyed by the gymnotus which it is unable to swallow, and after repeated attempts finds itself obliged to abandon. It appears that the strength of the shock which the gymnotus can give, increases with its size; and it is stated that there are some in Surinam river, whose length is twenty feet, and whose shock will immediately kill a man; they are therefore greatly dreaded by the inhabitants of those parts. They are nevertheless an article of food, and even by some esteemed a delicacy.

The gymnotus retains its electrical properties for a considerable time after death, but gradually decaying in strength. A gymnotus of three feet in length is generally between ten and fourteen inches in circumference. The animal has two pair of electrical organs, one pair being larger than the other, and occupying most of the longitudinal parts of the body.

The electrical properties of the gymnotus are exactly similar to those of the torpedo, but of greater strength. Its strength is so much greater, that it will pass through a small interruption in the circuit, as from link to link of a stretched chain, or across the incision made with a penknife in a slip of tin-foil pasted on glass, in doing which it will give a spark distinctly visible in a dark room.

The electrical powers of the gymnotus are dependent on its will, and exercised with the greatest force under irritation. The fish avoids non-conductors or interrupted circuits placed in the same water with it, but as soon as the circuit is completed, it approaches and gives the shock.

Of the third fish capable of giving the shock, but few particulars are known. It is called the *silurus electricus*, and is found in the rivers of Africa. It is sometimes found to exceed twenty inches in length. The body of this fish is oblong, smooth, and without scales; the electric organ seems to be towards the tail, where the skin is thicker than on the rest of the body, and a whitish fibrous substance, which is probably the electric organ, has been distinguished under it. It is merely said in general that it has the power of benumbing like the torpedo, but we have no details of experiments made with it.

Several curious facts of spontaneous animal electricity have been occasionally noticed from the most ancient times; but they were considered as fabulous by those who had no ocular demonstration of them. Virgil declares that the hair of Ascanius emitted a harmless kind of flame, and Pliny often speaks of light shining round the heads of men. Scaliger

speaks of a white Calabrian horse, which, when combed in the dark, emitted sparks of fire. Instances of animal electricity of this sort are not only well attested, but the possibility of them may be rendered very apparent, by rubbing backwards the fur of the back of a cat, after the animal has been sometime before the fire, and its coat is thoroughly dry. Electrical sparks will generally be observed in the dark, and will be accompanied with their usual report.

According to Hemmer's experiments, the electricity of the human body is mostly positive. In 2422 experiments in which he examined his own electricity, he found it 1252 times positive, 771 times negative, and 399 times 0. His own electricity was commonly plus, when he sat at perfect rest in his usual chair; but if his feet happened to be cold, it was perceptibly negative. He found that by washing his hands and face in cold water, his electricity, which a moment before was strongly plus, always became either much weakened or entirely negative. By exposing himself to a cool air while well clothed, his electricity in like manner changed from positive to negative, or weakly positive. Bodily motion is by no means necessary for producing animal electricity: neither does it depend upon the movement occasioned by respiration. In a state of lassitude, the electricity of the body is generally negative; but intensity of thought renders it strongly positive.

OF THE THEORY OF ELECTRICITY, AND MISCELLANEOUS REMARKS.

Du Fay attempted to account for the phenomena of electricity, by supposing that they were produced by two distinct fluids. These fluids, it has been already explained, he called the vitreous and resinous electricities, and he supposed each kind to have a repulsive power with respect to itself, but that they had an attractive power with regard to one another. It is obvious, however, that to account for attraction and repulsion by the supposition of an attractive and repulsive power, affords no real explanation of the subject, and applies at the best only to the most simple and common cases of attraction and repulsion. If the two fluids existed, a body positively electrified ought to attract one negatively electrified more weakly than one not electrified at all, which is contrary to experience. At this time, it was imagined that the electric matter, whether consisting of one or more fluids, was elicited by friction from electric bodies; but Dr. Watson having proved, by the effects of insulation on the machine, that it was derived from the earth, a new train of ideas instantly presented

themselves. In the end, the Doctor concluded that all electrical phenomena might be accounted for from the excess or diminution of the quantity of electric fluid contained in different bodies. This theory was afterwards adopted by Dr. Franklin, and is almost constantly distinguished by his name.

After Dr. Watson had given his experiments and opinions on this subject to the world, several other ingenious persons exerted themselves in forming electrical theories; but they were entangled in difficulties, which required so constant a resort to assumptions for clearing them away, that Franklin, a lover of simplicity, fixing upon the grand idea of increase or diminution pointed out by Dr. Watson, endeavoured to shew that it formed the key of which philosophers were in search, and was fully competent to all purposes, when accompanied with proper explanations. Whether, therefore, this theory will in all respects bear the test of future ingenuity and discoveries or not, it has evidently met, upon the whole, with the most marked approval. It gave strength to it, when it was found that an electrical machine exhibited both the vitreous and resinous electricities at the same time, viz. the electricity of the insulated prime conductor was the same as that of excited glass, while the electricity of the rubber was the same as that of excited sulphur, sealing-wax, rosin, &c. We shall advert to objections against it, but must first observe, that it is comprised in the seven following propositions:

1st. The electric matter is one and the same in all bodies, and is not of two distinct kinds.

2nd. All terrestrial bodies contain a quantity of this matter.

3rd. The electric matter violently repels itself, but attracts all other matter.

4th. Glass and other substances, denominated electrics, contain a large portion of this matter, but are not to be penetrated by it.

5th. Conducting substances are permeable by it, and do not conduct it merely over their surface.

6th. A body may contain a superfluous quantity of the electric fluid, in which case it is said, according to this theory, to be in a positive state, or electrified plus; and when it contains less than its natural share, it is said to be negative, or electrified minus.

7th. By exciting an electric, the equilibrium of the fluid is broken, and the one body becomes overloaded with electricity, while the other is deprived of its natural share.

According to this hypothesis, the pores of all bodies are supposed to be full of this subtile fluid; and when its equilibrium

is not disturbed, that is, when there is in any body neither more nor less than its natural share, or than that quantity which it is capable of retaining by its own attraction, the fluid does not manifest itself to our senses. The action of the rubber upon an electric disturbs this equilibrium, occasioning a deficiency of the fluid in one place, and a redundancy of it in another. This equilibrium being forcibly disturbed, the mutual repulsion of the particles of the fluid is necessarily exerted to restore it, and covers the excited surface of the body with what is called an *electric atmosphere.* It is demonstrated by Earl Stanhope, that the density of the electric atmosphere diminishes exactly in proportion to the squares of its distance from the electrified body. If two bodies be both of them overcharged, the electric atmospheres repel each other, and both bodies, if at liberty to move, recede from one another to places where the fluid is less dense. For as there is supposed to be a mutual attraction between all bodies and the electric fluid, such bodies as are electrified must go along with their atmospheres.

So far it is supposed that the bodies spoken of are electrified positively; we have now to examine the solution offered of the effects of bodies electrified negatively. If both the bodies are exhausted of their natural share of this fluid, they are both attracted by the denser fluid existing either in the atmosphere contiguous to them, or in other neighbouring bodies, which occasions them still to recede from one another as if they were overcharged. This solution is liable to considerable objection, and has received various amendments, though none of them have been satisfactory. It has been argued, that as the denser electric fluid, surrounding two bodies negatively electrified, acts equally on all sides of these bodies, it cannot occasion their repulsion. Cavallo therefore takes into consideration the fact, that no electricity can appear upon the surface of any electrified body, except that surface is opposite to another body which has actually acquired the contrary electricity, and these contrarily electrified bodies are separated by an electric: that the air is in general the electric which is opposite to the surface of any electrified body, for as it is not a perfect conductor, it easily acquires a contrary electricity on a stratum of its substance, that is, at a little distance from the electrified body. He therefore supposes that bodies negatively electrified repel each other, in order that a quantity of air may be interposed between their surfaces, sufficient to acquire a contrary electricity at a little distance from the said surfaces. This is a plausible solution of a difficulty which Dr. Franklin, who, it appears,

when he formed his theory, was not aware of the repulsion between negatively electrified bodies, acknowledged, after being apprized of it, that he could not explain in a satisfactory manner.

The ready application of Dr. Franklin's theory to the solution of the phenomena of the Leyden phial, contributed greatly to his celebrity. The electric fluid is supposed to move with the greatest ease in bodies which are conductors, but with extreme difficulty in electrics. Glass is absolutely impermeable to it; hence it is supposed that all electrics, and particularly glass, on account of the smallness of their pores, are at all times so replete with this fluid, that no more can be thrown upon any part of them, except a like quantity escape from another part, and the gain be exactly equal to the loss. Supposing these premises to be true, the phenomena of charging and discharging a plate of glass is of easy explanation. In working an electrical machine in the usual manner, the electric fluid is supplied by the rubber from all the bodies which communicate with it. If the rubber communicate with nothing but one of the coatings of a plate of glass, while the conductor communicates with the other, that side of the glass which communicates with the rubber must necessarily be exhausted in order to supply the conductor, which must convey the whole of it to the side with which it communicates. By this operation, therefore, the electric fluid becomes almost entirely exhausted on one side of the plate, while it is as much accumulated on the other; and the discharge is made by the electric fluid rushing, as soon as an opportunity is given it by means of proper conductors, from the side which is overloaded to that which is exhausted.

It will be acknowledged, says Dr. Priestley, that while the substance of the glass is supposed to contain as much as it can possibly hold of the electric fluid, no part of it can be forced into one of the sides, without obliging an equal quantity to quit the other side: but it may be thought a difficulty, upon this hypothesis, that one of the sides of a glass plate cannot be exhausted, without the other receiving more than its natural share; particularly as the particles of the fluid are supposed to be repulsive of one another. But it must be considered, that the attraction of the glass is sufficient to retain even the large quantity of the electric fluid which is natural to it, against all attempts to withdraw it, unless that eager attraction can be satisfied by the admission of an equal quantity from some other quarter. When this opportunity of a supply is given, by connecting one of the coatings with the

rubber, and the other with the conductor, the two attempts to introduce more of the fluid into one of the sides, are made in a manner at the same instant. The action of the rubber tends to disturb the equilibrium of the fluid in the glass; and no sooner has a spark quitted one of the sides, to go to the rubber, than it is supplied by the conductor on the other; and the difficulty with which these additional particles move in the substance of the glass, effectually prevents its reaching the opposite exhausted side. It is not said, however, but that either side of the glass may give or receive a small quantity of the electric fluid, without altering the quantity on the opposite side. It is only a very considerable part of the charge that is meant, when one side is said to be filled while the other is exhausted.

The theory does not require that the whole of the identical electricity that surcharges one side of a phial should be conveyed to the other through the whole length of a long circuit. The same effects will follow, if it merely drive forward, to the exhausted side, the electricity which the conductors are actually possessed of, and the place of which it occupies. This might be illustrated by a phenomenon of a different nature; there is a tide at London-bridge, although the waters of the ocean never arrive there;—they only push back the water of the river.

The impermeability of glass to the electric fluid, required by the above theory, has been much contested. In the first place, the well known fact that thin glass is more easily charged than thick, induces the belief that the surfaces have a substantial communication; and the circumstance that if a spark be taken from a prime conductor by the knob of a coated jar standing upon an insulating stand, the knuckle presented at the same instant to the outside coating, will receive a spark, seems not easy to explain away. If the electric fluid cannot act through glass, whence comes this spark? and if it can act through glass, does it not also pass through it? or does it act where it is not? Another proof that glass is penetrated by the electric fluid is, that the electric shock cannot be sent over the surface of glass. If this substance were altogether impenetrable to this fluid, it seems most likely that it would run over the surface of glass very easily. But instead of this, so great is its propensity to enter, that a shock sent through between two glass plates, pressed closely together, always breaks them to pieces, and even reduces part of them to a powder like sand. Also in experiments where jars are broken in attempting to charge them very highly, the entrance of the fluid into the glass must necessarily be

admitted. In short, the only reason for supposing that the electric fluid cannot act through glass, is the supposition that there is an accumulation of electricity on one side of the glass; but this accumulation itself is by no means incontestably proved; and philosophers have certainly much reason to be attentive to the facts which relate to these two subjects. We shall only mention further, a theory which takes a middle direction: it is admitted that electricity enters glass, but enters only to form alternate strata in the positive and negative state; that these strata are formed on each side, and increase in number with the height of the charge; hence, if too high a charge for the thickness of the glass is attempted to be given, they meet, and form a communication which is attended with the breaking of the electric.

The force with which electrified bodies remain in contact, has, instead of attraction, been called *electrical cohesion*. An amusing instance of this is seen in Symmer's experiments on silk stockings. He had been accustomed to wear two silk stockings on the same leg, one of them white, the other black. When these stockings were drawn off together, nothing remarkable appeared; but if, while they were both on, he rubbed his hands several times over them, and then drew off the outer or black one by itself, he heard a crackling noise, and in the dark perceived sparks of fire between them. When the stockings were separated and held at a distance from each other, both of them appeared to be highly excited; the white stocking positively, and the black negatively. While they were kept at a distance from each other, both of them appeared inflated to such a degree, that they exhibited the entire shape of the leg. Two black or two white repelled each other with considerable force, but a white and a black one would, if permitted, rush together with surprising violence; their inflation subsiding at the same time, and entirely ceasing when they were in contact. On separating them, their electricity was renewed. At first Symmer found it required a force of from one to 12 ounces to separate them; at another time they required 7 ounces to separate them, which weight was twenty times that of a single stocking; and it was applied in a direction parallel to its surface. When one of the stockings was turned inside out, and put within the other, it required 20 ounces to separate them; though at that time ten ounces were sufficient, applied externally. Getting the black stockings new dyed, and the white ones washed, and whitened in the fumes of sulphur, and then putting them one within the other, with the rough sides together, it required three pounds three ounces to separate them. With

stockings of a more substantial make, the cohesion was greater. In like manner, electrical effects will be obtained by rubbing with the hand or other substances any small pieces of black and white silk. A number of experiments were made with black and white ribbons, which with slight difference in the mode of rubbing, or of the surfaces of the bodies in contact with them, acquired negative and positive electricity by turns.

Symmer also made some experiments on the electrical cohesion of glass, and was followed by others. The ensuing account will give some idea of the process used. A coated plate of glass was charged, and then the coating was taken off the negative surface, to which another uncoated and uncharged plate of glass was applied. A coating was then put on the uncharged glass, so that the whole resembled one coated plate consisting of two lamina. On making a communication between the two coatings, an explosion took place, and the cohesion of the plates ensued. If the plates were separated before the explosion, after they had been in conjunction for some time, the charged plate was positive on both sides, and the uncharged one negative on both sides. If after the explosion they were separated and joined alternately, a small circle of paper, placed under the uncharged plate, adhered to it upon every separation, and was thrown off upon every conjunction. This could be repeated five hundred times with once charging the plate.

The power of the electric fluid to produce transparency in its passage over or through bodies naturally opake, is one of those surprising facts which has excited much speculation. Hauksbee (whose experiment has been mentioned at page 190) first discovered this in the instance of pitch; and the electrification of eggs and similar experiments are only varieties of the same nature. These experiments militate against the opinion that transparency depends upon the rectilinear direction of the pores of bodies, and it has been conjectured that electricity alone is the cause of all transparency; it must be confessed, however, that the present state of the science leaves the reasoning in favour of this hypothesis but weakly analogical.

If we take two similar basins of water, and electrify one of them, it will be found to weigh less than the other, which proves that electricity promotes evaporation.

When a jar or battery is discharged, the electric fluid disturbs the electricity of every substance connected by a conducting body with any part of the circuit. Thus if a person hold one end of a chain or wire which is connected with the metallic part of a discharging rod, when the discharge is made,

he will feel some part of the shock, though by a long chain or wire he may be far removed from the circuit. The shock experienced under these circumstances is called the *lateral explosion*. The more imperfect the conductors of the circuit, the stronger it is.

A strong shock sent through metallic oxides, frequently reduces them to a metallic state.

A piece of gold and a piece of silver of the same bulk, gain, under the same circumstances, an equal portion of the electric fluid. Hence it appears that the capability of retaining this fluid, is not in proportion to the quantity of matter.

The greater the density of the air in which a jar is charged, the greater the charge which the jar will hold, provided the air be dry. This might lead us to conclude, that electricity is confined upon bodies either in part or altogether by the pressure of the atmosphere.

On approaching any body strongly electrified, the face is affected by a sensation resembling that which would be occasioned by its meeting a spider's web. This sensation is therefore called the *spider's web*, and is supposed to be occasioned by the electrification (and consequent rising up) of the hairs or down upon the face.

If a point be fixed in an electrified prime conductor, and the tongue be held near it to receive the electrical stream issuing from it, a peculiar taste will be perceived.

Bodies of any kind which have been long exposed to an electric stream, acquire a smell almost resembling phosphorus, and retain it for a considerable time.

The bodies of persons killed by lightning become putrid in a very short time, of which that of Richman was an example; and by electrifying dead animal substances, the same effect is hastened. As flesh-meat, in temperate climates and weather, is kept a few days before it is prepared for the table, in order that it may become what is called "tender;" and as this "tenderness" is nothing else than a state of incipient dissolution or putrefaction, it has been proposed to render flesh-meat just killed fit for the table by electrifying it, by which means this state of tenderness is superinduced almost immediately. Experienced housekeepers are well aware of the effects produced in their larder, as well as the spoiling of their liquors, during the weather which accompanies thunder and lightning.

Of Medical Electricity.

The ancients have transmitted to us their belief, that the shocks given by the torpedo had the power of curing many disorders incident to mankind. While the existence of a fish which could give a shock was doubted, it cannot be surprising that its medical influence should be considered as ridiculous. But when the existence of the fish, and the identity of its power with that of electricity, became evident, it was admitted that the ancients spoke from justifiable data.

In the infancy of electricity, that is, about the commencement of the seventeenth century, accounts were multiplied of cures next to miraculous performed by means of this newly-discovered power; but upon closer investigation it appeared, that most of these either had no existence, or were exaggerated by weak or interested men, and that mischief rather than benefit had occasionally been produced. The error of the early electricians consisted in giving strong shocks, which experience has shewn to be nearly in all cases improper. " One thing, however," says Cavallo, " appears to be a little remarkable, in favour of electricity as a medicine, that though it has often fallen into the hands of very unskilful and injudicious persons, who have applied it at random in all cases, without being capable of distinguishing either the nature of the disorder, or the degree in which it ought to be administered, yet it has seldom been known to be attended with any bad effects; the patient has generally been relieved, and very frequently cured, but the ill consequences have been even more rare than those of inoculation. Electricity differs from other medical applications in this, that it requires not so much a thorough knowledge of the distemper, as a peculiar nicety in conducting the operation. For, however paradoxical this may appear, it is certain that the electric shock is by no means prejudicial to persons in health, and therefore to electrify a sound part of the body along with a diseased one, can do no harm. The degree of electrization must be regulated rather by the patient's feelings, than by the species of disease, and therefore nosology is not an indispensably necessary branch of science to the medical electrician. There can be no doubt, however, that medical electricity will have every chance of being best applied, as well as improved, by skilful physicians, or surgeons, whose knowledge of anatomy as well as of nosology, will enable them to direct the electrical fluid to the most proper part of the body, and to pass it through the most minute

vessels, according to the nature of the disease, and the part of the body affected."

Insensible perspiration is one of the most important functions of the animal frame; and as it is promoted by electricity, it may fairly be inferred that electricity promises to render signal service in cases which will yield to no other power. The power of electricity, also, over the blood, is evinced by the fact of its increasing the force of its circulation. Thus on insulating and electrifying persons who have been bled in the arm, the blood has sprung up to a greater distance than before. The same treatment will cause a fresh wound to bleed anew. Hence it is probable that electricity may enable the phlebotomist to obtain a due quantity of blood, when the state of the body would otherwise render it impossible.

The medical application of electricity, requires but few instruments in addition to the common electrical machine; an electric jar, united with Lane's discharging electrometer; an insulating stool, of such a size that an ordinary chair may be set on it for the patient to sit in, and a pair of simple instruments called directors, are all that are necessary.

Lane's discharging electrometer, as used in conjunction with the electric jar, is represented at fig. 11, pl. III. The surface of the jar LM should not contain less surface than one of four inches in diameter, and six inches high; if exactly this size, and coated to within two inches of the top, it will contain about sixty-three square inches of coated surface. Upon the wire *g*, which, as usual, descends into and touches the inside coating of the jar, is fastened a ball *m*, from which proceeds the glass arm *n*, of the electrometer *n o q*. Upon the glass arm is cemented a piece of brass *r*, containing a spring socket, in which the wire *o q* slides backwards and forwards. The wire terminates at *o* in a ring, and at *q* in a knob or ball, and of course, from its sliding motion, can at pleasure be set nearer to or further from the knob *g*: it is, however, not necessary that the range of the knob *q* should be more than half an inch. Sometimes the wire *o q* is graduated, in order that the knob *q* may be set with more readiness and precision at a certain given distance from the knob of the jar. The convenience of this apparatus consists in its affording the means of obtaining any number of shocks that may be required of the same intensity, and this intensity will be greater or less in proportion to the distance between the balls *q* and *g*; because the greater this distance is, the more the electricity in the jar must be accumulated, before it will escape from the knob of the jar to the knob of the electrometer. From the ring *o*, must proceed a wire or chain to the outside coating of the jar,

and as the arm *n* is of glass, and generally covered with sealing-wax to render it less liable to become a conductor, by attracting moisture, the jar can only be discharged by the sparks which pass through the space between the knobs *g* and *q*, and thence through the chain P to the outside coating. When the shocks are to be given by means of this apparatus, to any particular part of the body, for instance to the arm, the chain P must be taken away, and a slender wire, T, applied to the ring of the electrometer, while another wire, X, is hooked to the stand H of the jar, or in any other way connected with its outside coating. The other extremities of the wires must be fastened to the wires of the instruments YZ, which are called *directors*. The handles of these directors are made of glass or any good non-conductor; to which is cemented by a brass cup, the wires *a a*, terminating in knobs. When the knob of the jar is in contact with the prime conductor, and an assistant is turning the machine, it is obvious that the charge of the jar, when it is high enough to pass from *g* to *q*, will now pass from the knob of that director, connected by the wire T with the electrometer, to the knob of the other connected with the outside of the jar, provided these knobs be held sufficiently near; and if the knobs be connected by any conducting insulated substance, the discharge will be made between them, whatever their distance. Suppose then, any part of the human body is to be electrified; for example, the arm, as shewn in the figure, let the person be insulated by placing himself upon the stool for that purpose, either standing upon it, or sitting in a chair, as may be agreeable, and let the balls of the directors be placed at the extremities of the part through which the shock is to pass, by which means that part will be electrified while the machine continues to be wrought. If the strength of the shock is found to give uneasiness, it may be moderated by lessening the distance between the knobs *q* and *g*. The shock may be converted into a stream of electricity by unscrewing the knobs from the wires of the directors, which then leave points exposed like the discharging rod. When shocks are administered, it is not absolutely necessary to use an insulating stool.

In the medical application of electricity, it is of importance to begin gently, and to persevere for some time. At first the electric fluid should be drawn by a metallic point, the person being insulated and connected with the prime conductor, and the metallic point communicating with the earth. If, after some days' trial, no abatement of the disorder ensues, and the electrification has not the favourable effect even of imparting an agreeable warmth, the electric fluid may be drawn by means

of a wooden point; next to a wooden point are sparks, and after these low shocks. The electrification, whether in using the directors or otherwise, may be made through the clothes, unless they be very thick. In administering small shocks through thick clothing, it will be proper to pass metallic points through the clothes, so as to be in contact with the skin.

In disorders of an inflammatory nature, electricity, as it is a stimulant, should not be resorted to, unless at the commencement of those of a slight and local nature, as of a catarrh, inflammation of the eyes, and swellings where suppuration has not actually commenced. In chronic rheumatism, and chronic complaints in general, electricity may always be applied with safety, and even if it should not effect a cure, it seldom fails to afford relief. The tooth-ach, when of rheumatic origin, and unattended with caries, seldom fails to yield to this application. Dr. Samuel Perry, of New Bedford, America, successfully applied electricity in two instances of locked-jaw; after bleeding, cathartics, antispasmodics, the warm bath, and opium applied internally and externally, had totally failed. In one case the complaint was entirely removed by three shocks, in the other by an occasional shock for a few days.

There is one method of applying electricity, the value of which has not been ascertained; it is that of electrifying a bath, whether of warm or cold water. This may be accomplished by lining the bath with non-conducting substances.

Abstract of Electricity.

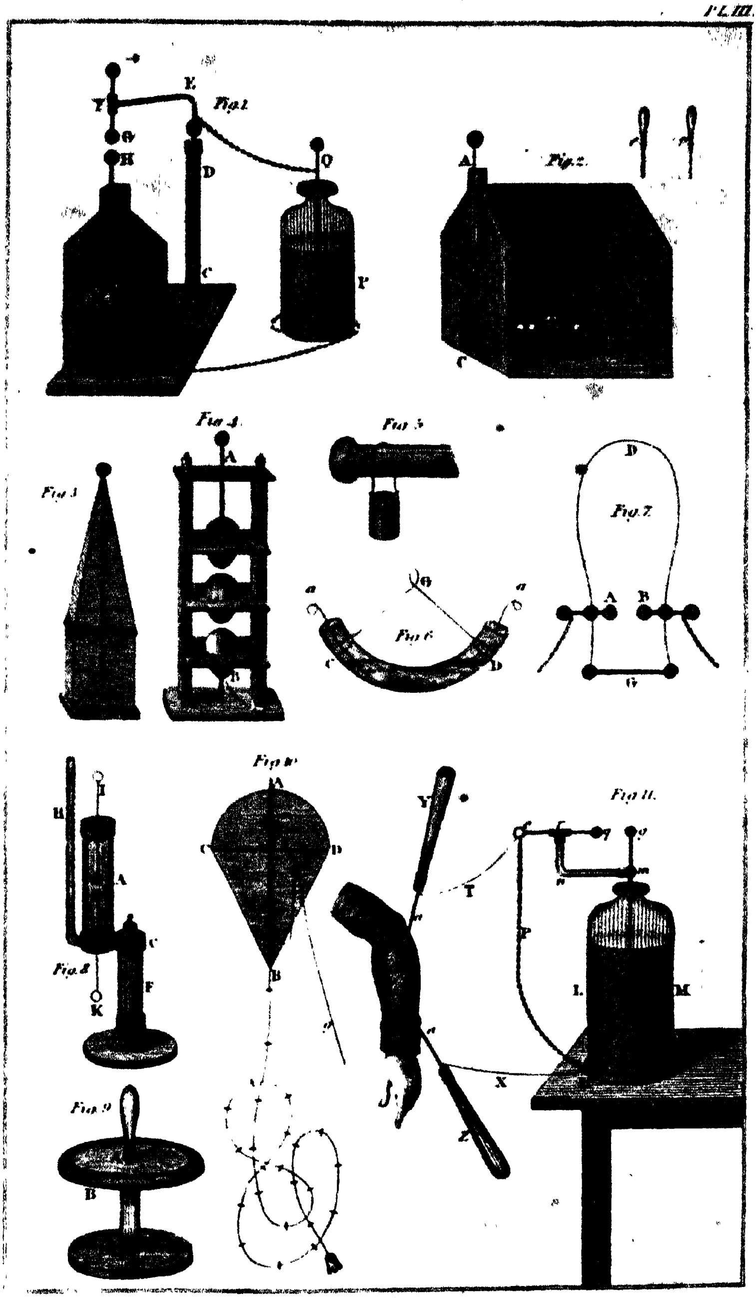
1. Electricity is supposed to be a fluid, which repels its own particles, but attracts all other matter.

2. That portion of electricity, which every body is supposed to contain, is called its *natural share.*

3. When a body is possessed of either more or less than its natural share, it is said to be *electrified* or *charged.*

4. If it possess more than its natural share, it is said to be *positively* electrified; if it contain less than its natural share, it is said to be *negatively* electrified.

5. Bodies through which the electric fluid passes freely, are called *conductors*, or non-electrics. Those bodies which oppose the passage of electricity, are called *non-conductors*, or *electrics*



Engraved by L. Davis.

Abstract.

6 Glass and some other bodies, which are non-conductors at common temperatures, become conductors when very hot.

7. The equilibrium of the electric fluid is disturbed by the friction of bodies against each other, and electricity is then said to be *produced* or *excited*.

8. Electricity is excited in the greatest quantity by the friction of *conductors* and *non-conductors* against each other.

9. The same substance, excited by a different rubber, will alternately be electrified positively and negatively.

10. Two bodies, both *positively*, or both *negatively* electrified, repel each other; whereas, if one body be *positive*, and the other *negative*, they will *attract* each other.

11. Upon this principle are constructed electrometers, or instruments for ascertaining whether bodies are electrified or not.

12. If a body containing only its natural share of electricity, be presented sufficiently near to a body electrified *positively* or *negatively*, a quantity of electricity will force itself through the air, from the latter to the former, appearing in the form of a spark.

13. When two bodies approach each other sufficiently near, one of which is electrified *positively* and the other *negatively*, the superabundant electricity rushes violently from one to the other, to restore the equilibrium between them. This effect also takes place, if the two bodies be connected by a conducting substance.

14. If an animal be placed so as to form part of this circuit, the electricity, in passing through it, produces a sudden effect upon it, which is called the *electric shock*.

15. The motion of electricity, in passing from a positive to a negative body, is so rapid, that it appears to be instantaneous.

16. When any part of a piece of glass or other electric is presented to a body electrified positively or negatively, that part becomes possessed of the *contrary* electricity to the side of the body it is presented to; and the other side of the glass is possessed of the *same* kind of electricity as the other body.

17. The electricity communicated to glass and other perfect electrics, *does not spread*, but is confined to the part where it is communicated, on account of the non conducting quality of the glass.

18. To effect the communication, and to enable it to be applied to the whole surface, the glass is covered on both sides with tin-foil, or some other conductor, in which case the glass is said to be *coated*.

Abstract.

19. If a communication by means of a conductor, be made between the two sides of a glass thus *coated* and *charged* with electricity, a *discharge* takes place, by which the two sides recover their natural state.

20. The coated glass may either be flat or in any other form; but cylindrical jars are found to be the most convenient form. The Leyden phial is nothing more than a glass of this description.

21. When several jars or phials are connected together so as to be charged and discharged simultaneously, they constitute an *electrical battery*.

22. Electricity is capable of producing the most powerful effects—melting the metals, and firing all inflammable substances.

23. The machines by which electricity is artificially accumulated, for the purpose of charging jars or batteries, are constructed with either a *cylinder* or *plate* of glass, which is whirled round in contact with a body called a rubber, and the electricity is taken off as it is produced, by a non-electric called the *prime conductor*.

24. Cylinder machines are the most easily constructed; but plate machines are the most compact and elegant.

25. Several bodies become transparent during the passage of electricity through them; a circumstance which has given rise to the conjecture that electricity may be the cause of all transparency.

26. *Metallic points* attract the electricity from bodies, and discharge them *silently*. This property has rendered them useful in defending from lightning.

27. When electricity *enters* a point, it appears in the form of a *star*; when it *issues* from a point, it puts on the appearance of a *brush* or *pencil*.

28. Machines may be put in motion by the electric fluid which issues from a point.

29. The shock of an electrical battery, will communicate magnetism to steel bars lying in or near the magnetic meridian; and a magnetic bar may have its poles reversed, or its magnetic properties destroyed, by imparting the shock while it is in different positions.

30. Electricity is evolved in the heating and cooling of various bodies; also in the evaporation and condensation of vapour.

31. Vapour requires for its natural share, a greater quantity of electricity than the water from which it was produced

Abstract.

32. When a quantity of vapour is any degree condensed, it has, therefore, electricity to give out, that is, it is in the positive state; when a quantity of vapour is further expanded, it requires for its natural share more electricity than before, that is, it is in the negative state.

33. By the ascent of vapour, immense quantities of electricity are carried from its reservoir the earth, and by the unceasing alternations of rarefaction and condensation, the atmosphere is always more or less in an electrical state.

34. *Lightning* is a vast accumulation of electricity.

35. *Thunder* is the noise produced by the solid particles of air rushing together, after having been separated by lightning, the rapidity of the motion of which is such as to produce a vacuum as it proceeds.

36. In the eruptions from volcanoes, lightning is almost always present; and earthquakes are generally accompanied by a disordered state of the atmosphere, often with great thunder-storms. Hence electricity is supposed to be intimately connected with these phenomena.

37. In the healing art, electricity appears capable of producing in many cases, the most excellent effects: in applying it, the general rule is to begin gently, and to continue the application, at periodical intervals, for a considerable time.

GALVANISM.

The electricity evolved by the mere contact of conducting substances, is called *galvanism*; a name given to this branch of science in compliment to Galvani, a celebrated physiologist of Bologna, in Italy, whose investigations first directed the attention of the public to the phenomena it comprehends.

While Professor Galvani was employed in the dissection of some small animals, his wife observed that a dead frog, lying near the prime conductor of a common electrical machine, was much agitated when one of his assistants happened to bring the point of a scalpel near its crural nerves; Galvani, on being apprised of the circumstance, endeavoured to obtain a repetition of the effect, and found that the convulsions of the animal could be produced at pleasure, by drawing a spark from the prime conductor, at the time the scalpel was in contact with the nerve.

The novelty of the fact which Galvani had thus been led to observe, stimulated him to pursue with ardour the track which had been opened to his view. His experiments were accordingly numerous, and he developed many interesting facts, which he communicated to the public in a work published in 1791. He found that a prepared frog, that is, the hind legs of a frog with its crural nerves laid bare, constituted an electrometer of exquisite delicacy, being agitated by degrees of electricity far too minute to affect the best inorganic electrometer. An entire frog did not evince the same susceptibility, because its course was more extended. Electricity drawn from the atmosphere in the ordinary manner by means of a kite, produced the same effects on animals, according to its intensity, as that of the machine.

Accident again assisted Galvani in his researches: having suspended some frogs from the iron palisades which surrounded his garden, by means of metallic hooks fixed in the spines of their backs, he observed that their muscles contracted frequently and involuntarily, as in the cases above-mentioned from electricity. He at first thought that these effects might be dependent on a particular state of the atmosphere; but this conjecture was refuted by the discovery, that the same movements could be produced at any time, by touching the

animals with two different metals, which at the same time touched one another either immediately or by the intervention of some other substance capable of conducting electricity. The contractions were stronger when a metallic coating, such as tin-foil, was applied to the nerve.

Galvani supposed that the convulsions he had observed were produced by a disturbance of the electricity inherent in animals, which was identical with the nervous fluid, and that the metallic substances employed had not any other effect than that of transmitting the electricity from the muscles to the nerves, or from the nerves to the muscles, which produced the contractions. This hypothesis was opposed by Volta, who found that he could excite contractions in the limbs of animals, when the conducting circuit only touched two parts of the nerve, two muscles, or two parts of the same muscle, provided two different metals were used. To explain the phenomena, he had recourse to the experiments of Bennet, who had some time before observed, that when plates of different metals were brought into contact, one of them transmitted a portion of its electricity to the other, and when separated they evinced signs of opposite states of electricity. When the plates, for instance, were one of copper and the other of zinc; the former, while the two were in contact, gave a portion of its electricity to the latter. Hence, when they were separated, and examined by the electrometer, the copper exhibited signs of negative electricity, and the zinc those of positive. Volta therefore concluded, that the electricity evolved in the experiments in question, arose from the contact of the different metals, and the convulsions of the animals operated upon, were merely the consequences of the stimulus applied to their nerves and muscles, which were thus evinced to be most delicate electrometers.

The first stage or epoch in the history of galvanism, must be considered that in which it was observed that excited electricity produced muscular contractions in dead animals; the second, is that in which it was observed that different metallic bodies, by mere contact, produced the same kind of contractions; the third, and most remarkable one, commences with Volta's admirable discovery of the means of accumulating the galvanic influence. This invention, which justly confers so much celebrity on its author, is, in galvanism, analogous to that of the Leyden phial in common electricity, and became, like the phial, the precursor of the most brilliant discoveries; and philosophers can as yet form but a very imperfect judgment of the importance of the consequences to which it will lead. It is called the Voltaic pile, and consists in

combining the effects of a number of plates of different metals, by which means a galvanic battery, capable of giving a shock, is constituted. As silver and zinc had been found, when a single piece of each was employed, to have the greatest effect in producing muscular contractions, these metals were selected by Volta for his battery. The silver plates generally consisted of coins, and the plates of zinc were of the same size. The like size and number of pieces of cloth, pasteboard, or leather, steeped in a solution of common salt, were also provided. These substances were piled upon each other in the following order: first zinc, then silver, then wet cloth; then again zinc, silver, wet cloth; till, by this regular alternation, the pile became sufficiently high. If the height of the pile was considerable, it was usually supported by three pillars of glass or varnished wood. The pile thus formed, was found to unite the effects of as many pairs of plates as it contained. A pile of 50 pairs of plates, with as many corresponding pieces of wet cloth, was found to give a pretty smart shock, similar to an electric shock, every time that a communication was made between the top and bottom of the pile. It was found, however, that little or no shock was perceived, when the hands, or other parts applied, were not previously moistened. It was also observed, that the effects were increased when a larger surface was exposed to the action of the pile. If the communication were made by touching the pile with the tip of each finger merely, the effect was not perceived beyond the joint of the knuckle; but if a spoon, or other metallic substance, were grasped in moistened hands, the effect was felt up to the shoulder. If the communication be formed, between any part of the face, particularly near the eyes, and another part of the body, a vivid flash of light, corresponding with the shock, is perceived. This phenomenon may be more faintly observed, by placing a piece of silver, as a shilling, between the upper lip and the gum, and laying a piece of zinc at the same time upon the tongue; upon bringing the two metals into contact, a faint flash of light generally appears. It is singular, that this light is equally as vivid in the dark as in the strongest light, and whether the eyes be shut or open.

The construction of the Voltaic pile is represented at fig. 1; a piece of wood, *a*, admits the three rods through three holes which it contains; its use is to press down the pile, and to keep the various surfaces in contact. The piece of cloth or card should be rather less than the discs of metal, and though well moistened, they should not drip, but be gently squeezed before they are applied, in order that no liquid may run down

the pile, or insinuate itself between the pieces of metal. The action of the pile may be perceived as long as the moisture of the cloth or pasteboard continues, but in a short time after it is constructed, it begins to diminish in strength.

Volta contrived another variety of the galvanic battery. The pairs of plates were soldered to each end of a bit of wire, which was afterwards bent into an arch, so that the plates became parallel to each other. Glass cups were then filled with a solution of common salt, and ranged side by side; the metallic arcs were so placed, that the silver plate was immersed in one glass, and the zinc in another, and each glass, except the extreme ones, contained one plate of each metal. This apparatus is represented at fig. 2. Its effects are similar to those of the pile, when the circuit is completed by a communication between the liquid of the first and last glass.

The Voltaic pile, as well as the battery last described, are now but little used, having been superseded by batteries of more convenient form, particularly when a great accumulation of galvanism is required. In using the pile, for example, it is tedious, after the cloth has become dry, to take the whole of the pile in pieces to moisten it, and the battery with glasses is deficient in compactness. Cruickshank, of Woolwich, therefore invented a battery commonly called, from its form, the galvanic trough. It is represented at fig. 3. It consists of a trough of baked wood, about three inches deep, and three inches broad. The two sides, *a b*, of this vessel, contain a number of perpendicular grooves, opposite each other, and about three-eighths of an inch apart. Into each pair of these opposite grooves is put a plate of zinc and silver, or zinc and copper, soldered together at the edges. These double plates are fastened in the grooves by means of a cement composed of five parts of rosin, four of bees-wax, and two of powdered red ochre. All the cells between the plates must be perfectly water-tight, and care must therefore be taken to run in the cement so as to secure this point. It will be found convenient, and will facilitate the business of fixing the plates, if they be heated till they can only just be handled, and smeared at the edges with the cement before they are put in. Any communication between the cells would destroy the effect.

The order of metals in a trough, must be the same as in the pile; that is, the different metals must be next each other, and supposing zinc and copper to be used, if zinc be the outermost at one end, copper must be outermost at the other.

The length of the trough is of course determined by the number of plates it is to contain, and the general rule is, not

to make the troughs heavier than one person can conveniently lift: 50 pairs of plates are a common number.

The plates need only be soldered together at their upper edges, because the other edges are secured by the cement. At the soldered edge, the copper is doubled over the zinc, in a degree equal to the thickness of the latter, and solder is then applied with more ease, because a groove to contain it may be left between the two metals.

The plates should not be quite equal to the depth of the trough, for the convenience of filling: as when they do not reach the top, by leaning the trough on one side, each cell will receive an equal quantity of fluid.

When the plates are properly fixed, the kind of fluid with which they are to be filled must be considered; water will answer only in a very slight degree; it has been found that the effect of the trough is greatly increased by the use of liquids which are capable of oxidizing, or exerting a chemical action on at least one of the metals, the water is therefore acidulated, or some common salt or muriate of ammonia is dissolved in it. Having filled the cells, the uppermost edges of the plates must be dried with a towel, to prevent any communication that way.

When a communication is made between the first and the last cell, the same effects take place as when a communication is formed between the top and bottom of Volta's pile, only in degree proportioned to the difference of acting surface.

In performing experiments, the communication between the extremities of a battery is usually completed by inserting a wire, as *e f*, fig. 3, at each end, and the extremities of these wires being brought nearly into contact, the galvanic action is exerted on any substance interposed between them, by which means very slender wires, or thin leaves of metals, or pieces of charcoal, may be deflagrated: the action of galvanism upon inflammable bodies is astonishingly powerful, and the exhibition of it upon metals is particularly interesting.

The wires may be retained in their situation in the trough, by being fastened to a small weight put into the cell, or by attaching them to a hook below the surface of the fluid. Copper wire is most commonly used, but platina wire is still better. In order that the experimenter may direct both the wires at the same time, without being himself affected by the galvanic fluid, the wires are passed through short pieces of glass tube, *m n*, and glass being a non-conductor of galvanism as of electricity, he can take hold of these tubes with safety.

The action of a battery is greatest when it is first filled with the fluid, and it declines in proportion as the action of the fluid

on the metal becomes weaker; till at length it becomes so small as to be inadequate to the purpose of experiment. To renew its original strength, therefore, it is necessary to pour off the fluid, and to clean the oxidated surface with a file or sand-paper, or by pouring weak muriatic acid into the cells, and afterwards rubbing the metals with a cloth.

When a great accumulation of galvanism is wanted, it may be obtained by a combination of troughs, as represented at fig. 4. Pieces of copper, *a b c*, bent so as to dip into the adjoining cells, connect the troughs together, and the wires connected with the ends AB, act on substances with the accumulated force of the whole number of troughs employed. In thus connecting batteries, care must be taken that the zinc end of one trough be opposed or next to the copper end of another.

Copper is here and elsewhere almost always spoken of as the metal used along with zinc; because, though silver is better, the difference is not great, and the value of silver is an obvious reason for the preference of copper.

The latest improvement of the galvanic apparatus, consists in giving greater facility to its construction. This is accomplished by the use of Wedgwood-ware or porcelain troughs, formed in the manufacture with compartments about half an inch broad, but about the same depth and length as the plates of ordinary troughs. Single plates of zinc and copper, are united by a metallic arch at the top, so that they are parallel to each other, and at such a distance that the two plates can be placed in two adjoining compartments. When the battery is completed, each compartment is filled with fluid, and contains a plate of copper and a plate of zinc. This apparatus in fact combines the principle of the battery with glasses and that of the common trough. It has, from its convenience, been much used at the Royal Institution. As both surfaces of the metals are exposed to the action of the fluid, plates of the same size as those of the common trough expose twice the surface to oxidation; the galvanic effect is not, however, duplicated, although rather greater than with a single surface. The principal advantage consists in the facility with which the battery can be constructed, and the plates cleaned after having been used: it also admits of another adjustment, which is occasionally convenient; the plates are sometimes all united by a bar along the top of them; and they may then be raised or lowered by rack-work at pleasure, so that the charge can be reduced in any required proportion, and again increased to its full quantity.

General View of Galvanism.

It has been much contested, whether galvanism and electricity are owing to the operations of the same fluid; but the question appears to be now fully decided in the affirmative. A principal argument in favour of their being different, was, that galvanism decomposed water, an effect of which electricity was not known to be capable. But Dr. Wollaston not only decomposed water by electricity, but produced by the same agent, a variety of other effects, which had been previously considered as exclusively producible by galvanism. It appears, therefore, that the principal difference between electricity and galvanism, consists in the mode of exciting, accumulating, and applying the fluid.

It will be proper to observe; that the conductors of galvanism are divided into two classes: the first class includes dry and good conductors, such as metals and charcoal; the second class includes water and other oxidizing fluids, and the substances which contain these fluids. This second class might be subdivided into species; for substances not themselves good conductors, if merely containing or moistened with a fluid, are not equal in conducting power to the fluid itself.

From the various researches of philosophers, the following results have been obtained:

In common electricity, the fluid is excited by the rubbing of an electric or non-conductor, and without the electric no effect of this sort can be produced: in galvanism, the fluid is excited by the conductor alone, without the intervention of electrics, being evolved by the chemical agency of the sub stances employed: for Sir H. Davy discovered, that the electricity is produced by a chemical action of the different substances on each other, that the effect is greater or less in proportion as this action is so, and that therefore two dissimilar metals are not essential to the evolution of galvanism.

To produce the galvanic action, three different substances at least, which are conductors of electricity, must be placed in contact, so as to form a circuit from one to another; for no sensible effect is produced from two conductors, nor from three when the communication between any two of them is broken by an electric: hence such a combination of three different conductors is called a simple galvanic circle. This circle may be variously formed: thus if a liquid, as diluted muriatic acid, be put into the vessel AB, fig. 5, and two wires inserted through the cork at B, as the wire *z* of zinc, and the wire *c* of platina,

silver, or copper, while the wires remain separated at the top, no action takes place on the wire *c*, but as soon as the circuit is completed by bringing the wires into contact at the top, the galvanic action is perceived by the evolution of gas from the wire *c*; separate the wires, and the effect ceases, connect them again, and it is renewed. Thus we see that the circuit must be completed, in order to occasion these striking phenomena, as here the wire *z* communicates with the liquid, the liquid with the wire *c*, and the wire *c* again with the wire *z*, forming, as above stated, a simple galvanic circle. In like manner, if the tube AB, fig. 6, be filled with a liquid, and wires of different metals be inserted through the corks A and B, and these be made to communicate at CG, the circle will be formed, and the like appearances will ensue. These effects will likewise take place, if the wires, instead of being brought into contact, be connected by any good conductor, which has no particular chemical action on the others. When the circle is formed, as above, by two conductors of the first class, and one of the second, it is called a galvanic circle of the first order; but when two of the conductors are of the second class, and one of the first, a galvanic circle of the second order. Thus let one of the glass vessels, AB, fig. 7, be filled with diluted nitrous acid, and the other with water, and connected by the copper wire *a b*, a simple galvanic combination is formed of the second order. If one extremity of a prepared animal be placed in one of the vessels, when the other extremity is brought into contact with the liquid of the other vessel, convulsions will take place. The combination will be more powerful, if a solution of sulphuret of potash be put in the glass vessel BD, fig 8, and a silver cup, or salt-cellar A, nearly filled with diluted nitrous acid, be placed within it, the communication between the liquids being formed by the prepared animal, the convulsions are strongly excited by the galvanic influence. If the three conductors be all of the first class, or all of the second, then the effect is seldom sensible. In this case, such conductors of the second class as differ more from each other, are more likely to produce a sensible effect than those of the first class. But a proper, active, simple combination, must consist of three different bodies, viz. of one conductor of one class, and two different conductors of the other class. Thus (denoting the bodies of the first class by means of large capital letters; and those of the second class by small letters) the combinations of figs. 9 and 10 are active; but those of figs. 11, 12, 13, 14, 15, are not active; because that of figs. 11, 12, or 13, consists of two bodies only, and that of fig. 14, and 15, consists of three bodies, of which two are of the same sort,

and of course act as a single body. In a single active galvanic combination, or, as it is commonly called, in a simple galvanic circle, the two bodies of one class must touch each other in one or more points, at the same time that they are connected together at other points by the body of the other class. Thus when a prepared frog is convulsed by the contact of the same piece of metal in two different places; then the fluids of those parts, which must be somewhat different from each other, are the two conductors of the second class, and the metal is the third body, or the conductor of the first class. If two metals are used, then the fluids of the prepared animal, differing but little from each other, may be considered as one body of the second class. Thus also, when a person drinks out of a pewter mug, the saliva or moisture of his under lip is one fluid or one conductor of the second class, the liquor in the mug is the other, and the metal is the third body, or conductor of the first class.

It seems to be indispensably requisite, that in a simple galvanic circle, the conductor or conductors of one class should have some chemical action upon the other conductor or conductors; without which circumstance the combination of three bodies will have either no galvanic action at all, or a very slight one. Farther, the galvanic action is evidently proportionate to the degree of chemical agency; which seems to shew that such chemical action is the primary cause of the electric phenomena. The most active circles of the first order, are two solids of different degrees of oxidability, and a fluid capable of oxidating at least one of the solids. Thus gold, silver, and water, do not form an active galvanic circle; but the circle will become active, if a little nitric acid, or any fluid decomposable by silver, is mixed with the water. A combination of zinc, silver, and water, forms an active galvanic circle, and the water is found to oxidate the zinc, provided the water holds some atmospherical air, and especially if it contains oxygen gas. But zinc, silver, and water containing a little nitric acid, form a more powerful galvanic circle, the fluid being capable of acting both upon the zinc and upon the silver. The most powerful galvanic combinations of the second order, are when two conductors of the second class have different chemical actions on the conductors of the first class, at the same time that they have an action on each other. Thus copper, or silver, or lead, with a solution of an alkaline sulphuret, and diluted nitrous acid, forms a very active galvanic circle.

After Volta had discovered the pile, it became an interesting object of inquiry to ascertain, with as much minuteness as possible, the combinations of substances which produced the greatest effect. A vast number of experiments were tried with this view by different persons, and at the Royal Institution, by which the following results have been obtained:

Galvanic Circles of the First Order, viz. which consist of two Conductors of the First Class and one of the Second.

Zinc with gold, or charcoal, or silver, or copper, or tin, or iron, or mercury; and water containing a small quantity of any of the mineral acids.

Iron, with gold or charcoal, or silver, or copper, or tin, and a weak solution of any of the mineral acids, as above.

Tin, with gold, or silver, or charcoal, and a weak solution of any of the mineral acids as above.

Lead, with gold, or silver, and a weak acid solution, as above.

Any of the above metallic combinations and common water, viz. water containing atmospherical air, or especially water containing oxygen air.

Copper, with gold or silver, and a solution of nitrate of silver and mercury; or the nitric acid; or the acetous acid.

Silver, with gold, and the nitric acid.

Galvanic Circles of the Second Order, viz. which consist of one Conductor of the First Class, and two of the Second.

Charcoal, or Copper, or Silver, or Lead, or Tin, or Iron, or Zinc	with water, or with a solution of any hydrogenated alkaline sulphuret, capable of acting on the first three metals only;	and diluted nitrous acid, or oxygenated muriatic acid, &c. capable of acting upon all the metals.

The history of philosophy affords many examples of observations which have remained isolated and useless for ages, and which, though often denied or discredited, have by the progress of discovery grown into importance, and become parts

of a beautiful system; contributing at the same time essentially to the early maturity of some departments of knowledge. Hence those who have accurately detailed a single new phenomenon, which appeared to have no connection with any thing useful, or any thing known, have in fact often been performing a work which should give celebrity to their names, by the direction it has given to inquiry, and the light it has thrown on subsequent researches.

In galvanism, several instances of the kind alluded to have occurred, and some of them it may be curious to mention.

A long time prior to the establishment of galvanism as a science, it had been observed, that if two different metals were placed in contact under water, they were subject to a rapid oxidation, though the water had no perceptible action upon them when they were alone.

It had also been observed, that ancient inscriptions, made of mixed metals, were totally defaced; while those made of pure metals were in excellent preservation.

When metals have been soldered by means of other metals, they were found to tarnish about the places where they were joined; and the copper sheathing of ships, when fastened by means of iron nails, soon corrodes about the place where the different metals touch each other.

It had been generally affirmed, that porter drunk out of a pewter vessel, has a taste different from that drunk out of glass or earthenware.

It is now evident, that in all these cases, the metals produce these effects, by their galvanic action on each other.

The zinc end of a battery is considered to be plus or positive; the silver end, (or copper end, when copper is used with the zinc,) is considered to be minus or negative.

The effect of the galvanic battery is much greater in oxygen than in atmospheric air, and it ceases entirely in azote or hydrogen.

Galvanic batteries, containing an equal quantity of simjlar metallic surface, have different effects, if the size of the plates be different. The greater the *number* of the plates, the stronger is the shock which they will give; on the contrary, the larger the plates, the greater is their power of deflagration; the extent of surface being in each case supposed to be the same. Fourcroy, who made this remarkable discovery, found that six large zinc and silver plates, which only gave a slight shock, consumed wire rapidly.

Berthollet found that silver which had been used in galvanic experiments became brittle.

A double quantity of galvanism only consumes a double

length of wire; but with a double quantity of electricity, the length of wire consumed is as the square.

Different animals are susceptible of galvanism in very different degrees. In cold-blooded animals, this susceptibility sometimes continues for several days after death; in the more perfect animals, as man, it continues only for a few hours, and sometimes ceases in a few minutes. A fish, with the organization of its head completely destroyed by bruises, preserves its irritability longer than if it had not been thus treated.

Frogs have been found the most convenient subjects for galvanic operations. Galvani prepared these animals by skinning their legs when recently dead, (they are usually killed by decapitation,) and leaving the legs attached to a small part of the spine, but separated from the rest of the body. Any other limb may be prepared in a similar manner, viz. the limb is deprived of its integuments, and the nerve which belongs to it is partly laid bare. The strongest contractions are produced when the galvanic electricity is caused to pass through the nerve to the muscles. Frogs which have been galvanized, very quickly become putrid.

Perhaps most of those who try galvanic experiments merely for the purpose of amusement, would chuse to dispense with the operations of decapitating and skinning frogs. It may therefore be observed, that an ample proof of the power of galvanism over the dead animal muscle, may be obtained by galvanizing any animal killed for domestic use. It will only be necessary to point the wires from the battery, and to penetrate the skin with them, at the two parts between which a communication is intended to be made.

Only those animals can be convulsed by galvanism which possess distinct limbs and muscles; yet reptiles may be shewn to be affected by it: thus if a leech or a worm be laid upon a plate of zinc, and surrounded at a little distance by pieces of silver, for example half-crowns; every time the animal touches one of the pieces of silver, it will be observed to draw itself back.

The medical uses of galvanism cannot yet be fully estimated. In some cases it has proved beneficial; in others it has had no effect whatever; and in others an unfavourable effect has been attributed to it. The cases in which it is in general most eligible to try it, are those for which common electricity is proper and has failed. In instances of numbness, palsy, and suffocation, it has proved highly advantageous.

Various hypotheses have been offered to account for the phenomena of galvanism; but that which appears to be the

most comprehensive, considers them as of an electrical nature. During the combination of a metal, and perhaps of other substances with oxygen, a quantity of electricity, it is supposed, is liberated or generated. In proof of the similarity of electricity and galvanism, Dr. Wollaston observes, that both appear to depend upon oxidation; for an amalgam not liable to oxidation, as of gold and platina, will not excite an electrical machine, and the effect of any amalgam is in proportion to the ease with which it is oxidated.

To account for the difference in the effects between galvanism and electricity, it is asserted, and seems to be a well established fact, that galvanism is electricity in a state of little condensation. In proof of this, it is found that a common electrical jar or battery may be charged by means of a galvanic battery, one wire from which, for this purpose, must communicate with the inside, and the other with the outside coating of the jar: the charge is given in a moment, but it is low, and such only as the jar would receive from a few turns of the ordinary electrical machine. Hence it is not difficult to explain why the galvanic shock should be greatest from a numerous series of plates, while the largeness of the plates is most essential to deflagration; for the force of the electric shock depends upon the *intensity* of the electric fluid, while the combustion depends very much upon its *quantity*. If then six large pair of plates, and six hundred small ones, contain the same surface, and produce equal quantities of the electric or galvanic fluid; yet, as in the latter series, the product is confined to narrow limits, and acquires probably a fresh impulse from every addition to its quantity in passing from plate to plate through its lengthened course, it arrives at the extremity of the apparatus in a state of much greater intensity than when only few plates are employed.

The electricity of the torpedo and gymnotus electricus, has a considerable resemblance to galvanism; it gives a considerable shock, but has little power of any other sort; and might be well imitated by a vast number of minute plates, put in action by a fluid feeble in its power of oxidation.

The wire from the zinc end of a battery, if made of any oxidable metal, is oxidated; but if made of gold or platina, which will not oxidate, pure oxygen passes from it. The other wire affords hydrogen, and the proportions in which these gases are given out, are such as are requisite to form water; they are therefore, it is inferred, furnished by the decomposition of water. To account for the decomposition of water, it is conjectured, that the electric fluid has a strong

attraction for hydrogen, insomuch that it cannot pass through water without combining with a portion of this gas, in consequence of which affinity, the oxygen, which, with the hydrogen absorbed, forms part of the water, is necessarily set at liberty. It would exceed our limits, to enter with minuteness into the consideration of this subject; but we may refer to Nicholson's Journal, vol. 3, 8vo series, for Dr. Bostock's ingenious explanation of galvanic phenomena on electrical principles. The Doctor particularly remarks, that in the galvanic apparatus, the electric fluid is generated, and therefore its effects are much increased by insulation. Insulation, however, almost entirely suspends the action of an electrical machine; which therefore only transfers the electricity from one body to another.

We shall make but one remark more: the galvanic investigations of Sir H. Davy tend to establish an opinion that all substances which have a chemical action on each other, are in opposite electrical states, and that this difference of state is the cause of such chemical action. Evidence is, however, yet wanting, to confirm this beautiful hypothesis, and consequently it would be useless to shew how it ought to modify chemical, galvanic, and electrical theories.

Galvanic Experiments.

1. The most striking and the most common experiments are those which consist in the exhibition of the effects of the galvanic energy upon the organs of animals. If two metallic rods, or, what is equally convenient, two silver spoons be grasped one in each hand, the skin of the part being moistened with a solution of salt, and one of the spoons be brought in contact with one end of the battery the moment the other comes in contact with the other end of the battery, the shock is perceived. Fifty compound plates will give a shock which will be felt in the elbows. The shock from a hundred plates will be felt in the shoulders. A greater number of plates give so forcible a shock to the muscles as to be dreaded a second time. If the plates be from eight to twelve inches square, the effect will be continued until the acid in the cells is expended.

Several persons may receive the shock together, by joining hands, in the same manner as in receiving the shock from a Leyden phial. Their hands should be well moistened; but the strength of the shock diminishes as it proceeds, in consequence of which the last person feels it much less violently

than the first. It is remarkable, that some persons are unsusceptible of the galvanic influence, so that if they form part of the galvanic circuit, the experiment will not succeed until they are removed. After receiving the galvanic shock, a slight numbness of the part that has been exposed to it remains for some time.

2. The galvanic shock may also be conveniently given, by immersing the hands or the feet into vessels containing a solution of salt, and bringing wires from each end of the battery into the liquid. If any other part of the body, is intended to be operated upon, a sponge, moistened with salt-water and fastened to a metal plate connected with one end of the battery, may be applied to the part, and the hand or foot put into a vessel of the same liquid, connected by a wire with the other end of the battery. Small bits of sponge, or bits of leather, may be fastened to the end of the connecting wires, and made more or less moist as the delicacy of the part may require.

3. The decomposition of water by galvanism is easily effected. The most simple mode of performing this experiment, is to bring the wires coming from each end of the battery into a vessel of water. A profusion of bubbles of gas will appear to be given out from each wire, as far as they are immersed in the liquid. The nearer the wires are brought together, so as not to touch, the more rapidly the decomposition goes on. The gas produced from the wire coming from the zinc end of the battery, if the wire be of gold or platina, is found, as before mentioned, to be oxygen; but if the wire be of any more oxidable metal, no gas will appear, but the wire will be oxidated. The gas furnished by the wire from the copper end of the battery, of whatever kind of metal the wire may be, is pure hydrogen. If the immersed part of this, however, be previously oxidated, no gas will be observed for some time, the hydrogen being employed in reducing the oxide upon the surface. Both the gases are furnished by the decomposition of the water.

An apparatus more convenient for this purpose, and at the same time fitted for collecting the gases, is shewn at fig. 16; *e g* is a cup of glass capable of receiving the glass tube *h*; E *c* and F *z*, are two wires of platina, fitted into two holes perforated in the bottom of the glass cup; the tube *h*, which is close at the top, is first filled with the water or other liquid,

* This supposed fact rests upon the authority of several who state their having experienced it; but it appears too marvellous to be considered as absolutely true, until proved by experiments which admit no contrariety of inference.

and the cup inverted upon it; the whole is then suddenly returned into an erect position, and placed in the frame, fig. 17. In this frame, ABCD are four pieces of brass, united together by the pieces of glass F and G, and supported by four legs, through which also the brass rods, H and K, are passed. It is plain that the two sides of this frame are insulated with respect to each other, at least as much as is necessary for any galvanic experiment. The part F, in fig. 16, being introduced into any of the holes, such as *n m*, the opposite end E is made to rest on the opposite brass rod K. If the wires from the battery be now connected with the frame at H and K, the gas will instantly begin to rise from the wires *c* and *z* into the tube, while the liquid descends and occupies the cup.

5. A number of the apparatus, such as fig. 16, may be employed at the same time; and if the different tubes are filled with different liquids, such as the various solutions of salts, and the communication of each occasionally cut off, by placing some non-conductor at E, their relative conducting powers may be ascertained. If two tubes of smaller size be placed, one over the wire *z*, and the other over that of *c*, the gases may be collected separately. If the tube contains a metallic solution, such as silver, lead, or copper, the wire from the copper end of the battery will afford no gas, because the hydrogen that would be emitted in other cases, is employed in reducing the metal of the solution. Let the glass vessel A, fig. 18, have the two tubes Z and C ground into its two necks. At the ends Z and C of the tubes, are tied bits of bladder, so that any liquid in the tubes may have no tendency to enter the vessel A. The vessel being previously filled with some fluid, the tubes are so inserted that there may be no air between the end of the tubes; the ends are also provided with two small caps of ivory or wood, through which the platina wires *p p*, are passed, reaching to the bottom, but not piercing the bladders. The tubes being filled with water, and the wire from the zinc end of the battery connected with the wire of the tube Z, while that of the copper end is attached to that of the tube C, the decomposition of water will speedily commence, the wire in Z affording oxygen gas, while that of C affords hydrogen gas. In a very short time, the liquid of the tube Z will be found to contain muriatic acid, or rather the oxy-muriatic acid; and the tube C will at the same time be found to contain a fixed alkali. If the tubes be filled with an infusion of cabbage, the signs of alkali and acid are very soon observed, from the liquid of Z becoming red, and that of C green. If the connection be reversed, the liquids repass to the blue colour;

and if the process be continued, that of Z becomes green, and C red.

6. Batteries contain 6000 or 8000 square inches of zinc and copper surface, furnish the means of performing a variety of experiments, in which light and heat are abundantly extricated. Such a battery, in its highest state of energy, will make red-hot, and even fuse, a considerable length of fine steel wire, when it forms part of the circuit in making the connection between the two ends of the battery. Attach to the end of each wire of the battery, a small piece of charcoal; on completing the circuit, by bringing the two pieces of charcoal into contact, a light the most vivid the eye can behold, immediately appears. By alternately separating and joining the charcoal, the appearance may be repeated for some time. This experiment, and others of the same kind, should be formed in the dark; and the charcoal should be prepared for the purpose, by burning box-wood, lignum-vitæ, or some other hard close-grained wood in a close vessel.

The foils, or thin leaves of gold, silver, tin, and other metals, as well as small wires, may be deflagrated very conveniently by means of mercury. Let the conducting wire from one end of the trough or battery, terminate in the mercury contained in a small iron dish; to the other conducting wire attach the foil or wire to be deflagrated, and upon touching the mercury with the latter, the effect is produced.

The light afforded by the combustion of different metals is of different colours.—Copper or brass leaf, commonly called Dutch gold, burns with a green light, silver with a pale blue light, and gold with a yellow light, and all with a slight crackling or decrepitation.

The galvanic discharge fires gunpowder, hydrogen gas, oils, alcohol, and all other combustibles.

7. One of the most brilliant discoveries of modern chemistry was effected by the application of galvanism. We allude to the decomposition of the fixed alkalies, by Sir H. Davy. These alkalies, viz. soda and potass, were supposed to be simple bodies, but this philosopher discovered them to be *metallic oxides*. A small piece of one of these oxides being laid upon a plate of platina, connected with one end of a powerful battery, and another piece of platina, connected with the other end of the battery, being brought into contact with it, a portion of black matter is soon formed, in which is found imbedded small metallic globules. These globules are the base of the alkali, which has been deprived of its oxygen by the action of the battery. These metals will be more particularly noticed

under the head Chemistry; that from potass is called potasium, and that from soda is called sodium.

8. Aldini, the nephew of Galvani, is of opinion that the suggestion of his uncle, respecting the existence of animal electricity, ought not to be wholly given up. He exhibited a number of experiments at Guy's Hospital, many of which had the proof of this hypothesis for their object; the following experiments form part of his course:

Two prepared frogs were laid on the surface of a dry earthen plate, the opposite knees and the vertebræ communicating; as soon as a metallic arc was made by a bow of wire touching the nerve and muscle of one of the frogs, violent contractions took place in both.

9. Three prepared frogs were laid in the same order as in the last experiment, only the parts of the animals were not in contact, except by a streak of water drawn by the finger from one to the other across the plate. As soon as a metallic communication was made between the nerve and muscle of one, all the three were thrown into motion, and at the same instant. If glass bars, or metallic ones with a small portion of wax on one end, are used, no contractions are excited.

10. A prepared frog being held by the foot and a portion of the vertebre, and the other foot being brought in contact with a silver waiter, such violent contractions were excited as to cause the limb apparently to leap along the plate.

11. The operator having hold of the feet of a prepared frog with one hand, and by wetted hands communicating with three persons or more, the last person completed the circles by touching the vertebre; in doing which contractions instantly took place.

12. Two prepared frogs being laid in the order before-mentioned on an earthen plate, a third was laid between them reversed, the toes touching the vertebræ of the two. On a metallic communication being made, the two outward ones violently contracted, without any sensible effect on the middle one, though it served as the conductor to one.

13. Galvanic attraction was made sensible by the operator holding a prepared frog by its feet, placing the other hand on the spinal marrow of a dog, and bringing the sciatic nerves of the frog nearly in contact with the exposed ribs of the dog: the nerves were instantly attracted, and contractions tcok place.

14 On connecting the optic nerve with one end of the pile, and touching the iris of the eye with the other conductor, the pupil contracted.

Abstract of Galvanism.

1. Galvanism appears only to be a method of exciting electricity: the first efficient observation of its effects originated with Galvani, from whom it derives its name; but it was Volta who first rendered it interesting, by discovering the method of accumulating it.

2. Galvanic electricity is produced by the chemical action of bodies upon each other, particularly by the oxidation of metals, during which process considerable quantities are evolved.

3. It appears to be in a state of less intensity or condensation than the electricity obtained by the electrical machine.

4. It will oxidize metals, and set fire to all inflammable substances; it will also give a low charge to a Leyden phial.

5. Of all known substances, the nerves of animals recently dead, appear to be the most easily affected by it, and constitute electrometers of exquisite delicacy.

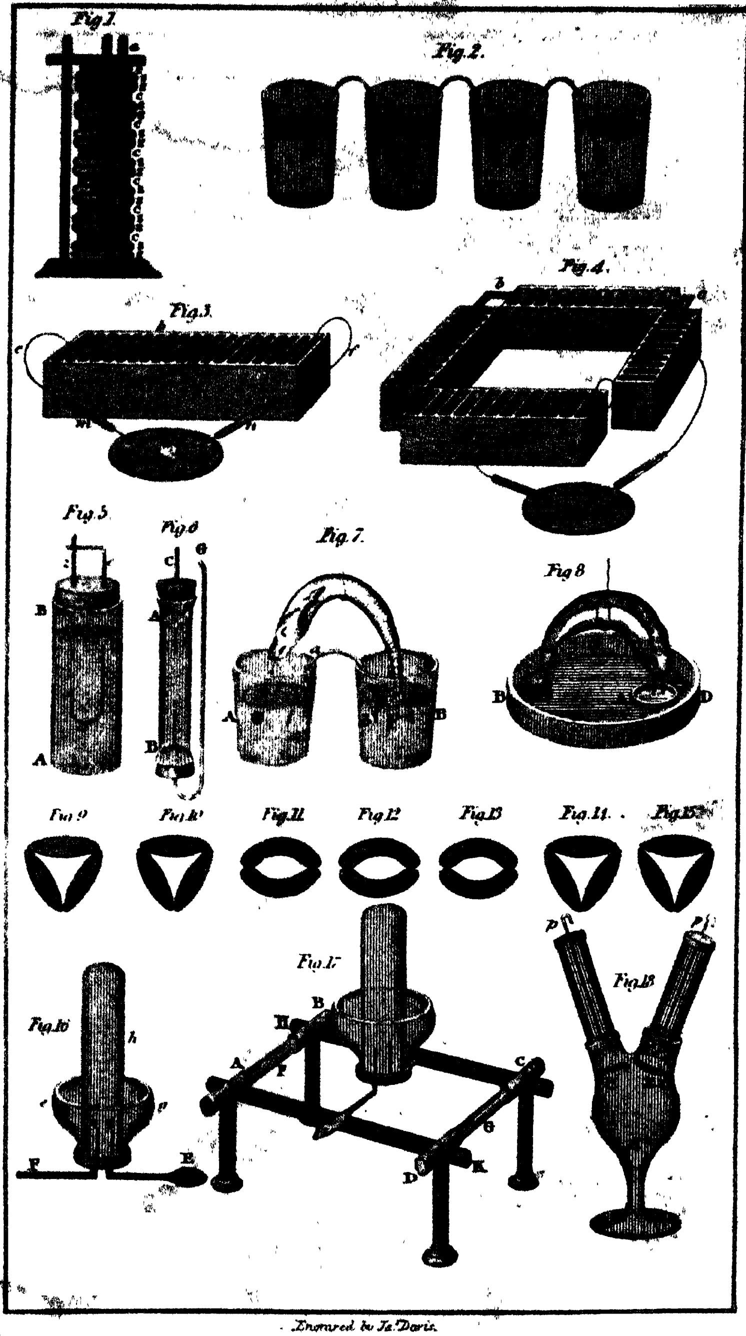
6. It is conducted and refused a passage by the same substances as common electricity.

7. When a living animal forms part of its circuit, it produces a sensation resembling that of the electric shock.

8. Electricity is *generated* by the galvanic battery, but only *collected* or *transferred* by the electrical machine; and therefore the effects of the former are increased by insulation.

9. The powe- of galvanism, in consuming wires, is greatest when the plates are numerous; but in giving a shock it is greatest when the plates are large; the quantity of surface in each case being the same.

GALVANISM.



Engraved by Ja. Davis.

CHEMISTRY

CHEMISTRY acquaints us with the various means of changing the properties of bodies, by their action upon each other, whether in a simple or compound state.

Chemistry is a science, the utility of which is as boundless as its extent. What grasp at the knowledge of terrestrial things can be conceived wider than that which embraces the action of all bodies, under all circumstances, upon each other; or what can be more important to the enjoyment of physical existence, than the best means of obtaining what this knowledge would give—whatever is most conducive to its welfare. The growth and preparation of food, in short, every process on which the comforts of life, and the manual performances of man, are dependent, can improve only with our knowledge of the properties of bodies which are the instruments we must use to minister to our wants.

To trace in a regular manner the history of chemistry, though a task not devoid of interest, would contribute nothing to the elucidation of the principles of the science. We shall therefore confine ourselves to such remarks of an historical nature as incidentally occur, and proceed immediately to useful details. We shall advert, 1, to the nomenclature of chemists, or the language which they use to designate the chemical state or differences of substances; 2, to that power of attraction between the particles of bodies upon which chemical changes depend; 3, to the apparatus and manipulations of the laboratory, by which the action of this attraction is modified; 4, to light and caloric, those unconfinable powers which so many of these manipulations elicit or require; 5, to simple substances in general; and 6, to compound substances.

Of Chemical Nomenclature.

From the revival of learning, after the fall of the Roman empire, to nearly the close of the seventeenth century, chemistry was chiefly confined to those who followed it with alchemical views. These persons, many of whom knew that they were deceiving their patrons, while others were desirous to conceal their self-delusion, or to create admiration, by the appearance of having done much, were anxious to give every product of their laboratories, a mysterious, extraordinary, or unintelligible name; as they did not act in concert, the same preparation obtained very different names; and as they were, with few exceptions, as eminent for ignorance as effrontery, and carried on their operations at random, they examined but superficially the substances which they undertook to denominate, and knew not to what they were indebted for their leading properties. Such names as *horn moon*, *mercury of life*, the *wonderful salt*, the *salt with many virtues*, form but a small specimen of a prodigious number, equally inappropriate and ridiculous. Hence, when the dreams of alchemy were broken by the dawn of a more enlightened day; when men who had the promulgation of truth only for their object, became chemists, from a persuasion of the advantages which the cultivation of that science would afford to mankind; they found it difficult to unravel the confusion which the misnomers of their predecessors had created. In proportion as discoveries were multiplied, the want of a regular and appropriate nomenclature increased, and formed a strong bar to the general diffusion of a taste for chemical researches. A few innovations, which were made by single individuals, in order to accommodate the language of chemistry to the improved state of knowledge, served only to shew how much was still wanted. It was perfectly obvious that names founded upon a mistaken view of the properties of things, tend to the propagation of erroneous opinions; and that when a vast number of substances are designated at random, without any connection in name, although nearly related in composition, the mere effort of memory to recollect these names, will exceed the effort which ought to be required for the acquisition of a science. Towards the close of the last century, therefore, several eminent French chemists determined to take a comprehensive view of the subject, and to remodel the whole system of chemical nomenclature, a task which they completed in 1787.

Their object was to reject all the old names which were known to convey false ideas, but to preserve those which were not of this class, and to which custom had given a currency scarcely, and not usefully, to be checked; they at the same time introduced new terms of appropriate derivation; and the method of forming compound terms, so as to indicate the composition of compound bodies, was pointed out. This system of nomenclature possessed so much merit, that the adoption of it soon became general in France, and from thence it spread with great rapidity to other countries, where it was received either entirely, or with such improvements as experience warranted. The objections which have been urged against it are futile; they have chiefly amounted to this; that it is not absolutely perfect, and will, by the progress of discovery, hereafter require to be modified. On the contrary, a high eulogium on its value and opportune establishment, is conveyed by the opinion of several eminent chemists, that the present state of chemistry could not be communicated, much less remembered, by the language previously in use.

The following table will exhibit the most important changes of terms which have been made, and more particular details will occur, as an account of each substance gives occasion:

Old Names.	*New Names.*
Acetous salts	Acetites.
Acid of vitriol, phlogisticated	Sulphurous acid.
.... of alum	Sulphuric acid.
.... of vitriol	Sulphuric acid.
.... vitriolic	Sulphuric acid.
.... of sulphur	Sulphuric acid.
.... of nitre, phlogisticated	Nitrous acid.
.... of nitre, dephlogisticated	Nitric acid.
.... of saltpetre	Nitric acid.
.... of sea-salt	Muriatic acid.
.... marine	Muriatic acid.
.... dephlogisticated marine	Oxygenized muriatic acid.
.... aërial	Carbonic acid.
.... of chalk	Carbonic acid.
.... cretaceous	Carbonic acid.
.... calcareous	Carbonic acid.
.... of charcoal	Carbonic acid.
.... mephitic	Carbonic acid.
.... of spar or fluor	Fluoric acid.
.... sparry	Fluoric acid.

Old Names.	*New Names.*
Acid of borax	Boracic acid.
.... of arsenic	Arsenic acid,
.... of tungsten	Tungstic acid.
.... of wolfram	
.... of molybdena	Molybdic acid.
.... of apples	Malic acid.
.... of sugar	Oxalic acid.
.... saccharine	
.... of wood-sorrel	
.... of lemons	Citric acid.
.... of cream of tartar	Tartaric acid.
... of Benzoin	Benzoic acid.
.... of galls	Gallic acid.
.... of amber	Succinic acid.
.... of ants	Formic acid.
.... of cork	Suberic acid.
.... of phosphorus, phlogisticated	Phosphorus acid.
.... of phosphorus, dephlogisticated	Phosphoric acid.
.... of silk-worms	Bombic acid.
.... of fat	Sebacic acid.
.... sedative	Boracic acid
.... of lac	Laccic acid.
.... of milk	Lactic acid.
.... saccholactic	Mucous acid.
.... of sugar of milk	
Air	Gas.*
.... dephlogisticated	Oxygen gas.
.... empyreal	
.... vital	
.... pure	
.... impure or vitiated	Nitrogen gas, or azote, or azotic gas.
.... burnt	
.... phlogisticated	
.... inflammable	Hydrogen gas.
.... marine acid	Muriatic acid gas.
.... dephlogisticated marine acid	Oxygenized muriatic acid gas.

* The term *gas* is now used as a general name for all kinds of air except atmospheric air.

*** New nomenclature.**

Old Names.	*New Names.*
Air, hepatic, ... fœtid of sulphur	Sulphuretted hydrogen gas.
.... fixed .... solid, of Hales	Carbonic acid gas.
.... alkaline	Ammoniacal gas.
Algaroth, powder of	White oxide of antimony by the muriatic acid.
Alkalies, fixed	Potash and soda.
Alkali, volatile	Ammonia.
.... concrete volatile	Carbonate of ammonia.
Alkalies caustic	Pure alkalies, or those deprived of carbonic acid.
.... effervescent, or not caustic, or aërated or mild	Alkaline carbonates, or alkalies combined with carbonic acid.
Alkali, vegetable	Potash.
.... mineral .... marine	Soda.
.... Prussian	Prussiate of potass.
Alum	Sulphate of alumine and potass.
Antimony, crude	Sulphuret of antimony.
.... diaphoretic	White oxide of antimony, by the nitric acid.
Aqua-fortis	Nitric acid of commerce.
Aqua-regia	Nitro-muriatic acid.
Aqua ammoniæ pura	Ammonia.
Argil, or argillaceous earth	Alumine.
Barilla,	Carbonate of soda.
Bezoar mineral	Oxide of antimony.
Black-lead	Hyper-carburet of iron.
Blue, Prussian	Prussiate of iron.
Borax	Borate of soda.
Butter of antimony	Muriate of antimony.
Calces, metallic	Metallic oxides.
Caustic, lunar	Fused nitrate of silver.
Ceruse	White oxide of lead by the acetous acid.
Ceruse of antimony	White oxide of antimony by precipitation.
Chalk	Carbonate of lime.
Charcoal, pure	Carbon.
Cinnabar	Red sulphuretted oxide of mercury.

* The potash of commerce, when purified, is now called potass.

New nomenclature.

Old Names.	New Names.
Colcothar of vitriol	Red oxide of iron, by the sulphuric acid.
Copper, acetated	Acetate of copper.
Copperas, green	Sulphate of iron.
.... blue	.... of copper.
Cream of tartar	Super-tartrate of potass.
Earth, calcareous	Lime.
...... aluminous	Alumine.
...... of alum	
...... siliceous	Silex.
...... ponderous	Barytes.
...... magnesian	Magnesia.
...... muriatic	
Egg, white of	Albumen.
Elastic gum	Caoutchouc.
Indian rubber	
Emetic tartar	Antimoniated tartrate of potass.
Essences	Volatile oils.
Ethiops, martial	Black oxide of iron.
.... mineral	Black sulphuretted oxide of mercury.
.... per se	
Flowers, metallic	Sublimated metallic oxides.
.... of sulphur	.... sulphur.
Fluors	Fluates.
Glass of bismuth	Vitreous oxide of bismuth.
Glue or jelly	Gelatine.
Glutinous matter	Gluten.
Gypsum	Sulphate of lime.
Hepars	Sulphures.
Heat, latent, or matter of heat	Caloric.
Kermes mineral	Red sulphuretted oxide of antimony.
Lapis infernalis	Fused nitrate of silver.
Leys	Solutions of alkalies.
Liquor silicum	Solution of siliceous potash.
...... of flints	
Litharge	Litharge, or semi-vitreous oxide of lead.
Liver of sulphur, alkaline	Sulphuret of potash.
.... calcareous	.... of lime.
Luna cornea	Muriate of silver.
Magistery of bismuth	Oxide of bismuth by the nitric acid.
.... of lead	Precipitated oxide of lead.

New nomenclature.

Old Names.	New Names.
Magnesia alba ...... aërated	Carbonate of Magnesia.
.... black	Black oxide of manganese.
Masticot	Yellow oxide of lead.
Matter, amylacious	Fecula, or starch.
Mephitis	Nitrogen.
Minium	Red oxide of lead.
Mother waters	Deliquescent saline residues.
Nitre Saltpetre	Nitrate of potash.
Nitres	Nitrates.
Oils, fat	Fixed oils.
.... essential .... ethereal	Volatile oils.
.... of tartar per deliquium	Solution of carbonate of potash.
Phlogiston, an imaginary principle, adopted by Stahl and his followers, to account for the phenomena of combustion. Its existence having never been proved, it has no name in modern science.	
Phosphoric salts	Phosphates.
Plumbago	Hyper-carburet of iron.
Precipitate, red	Red oxide of mercury by the nitric acid.
.... per se	Red oxide of mercury by fire.
Principle, astringent	Gallic acid.
.... tanning	Tannin.
.... acidifying	Oxygen.
.... inflammable, (identical with *Phlogiston*.	
Pyrites of copper	Sulphuret of copper.
...... martial ...... factitious of iron	.... of iron.
Realgar	Red sulphuretted oxide of arsenic.
Regulus of a metal	The metal in a state of purity.
Rust of copper	Green oxide of copper.
.... of iron	Carbonate of iron.
Saffron of Mars	Red oxide of iron.
Sal ammoniac	Muriate of ammonia.
... polychrest	Sulphate of potass.
Salt, common or sea	Muriate of soda.
.... febrifuge of Sylvius	Muriate of potass.

* In general the works in which it is used may be understood by substituting the term "hydrogen" instead of it; and by "dephlogisticated" understanding free from hydrogen

New nomenclature.

Old Names.	*New Names.*
Salt, fusible of urine	Phosphate of soda & ammonia.
.... Glauber's	Sulphate of soda.
.... Epsom	.... of magnesia.
.... of sorrel	Super-oxalate of potass.
.... of wormwood	Carbonate of potass.
.... vegetable	Tartrate of potass.
.... sedative	Boracic acid.
.... Stahl's sulphurous	Sulphite of potash.
Selenite	Sulphate of lime.
Spar, calcareous	Crystallized carbonate of lime.
.... fluor	Fluate of lime.
.... ponderous	Sulphate of barytes.
Spirit, ardent	Alcohol.
..... of nitre	Nitric acid.
..... of nitre, fuming	Nitrous acid.
..... of salt	Muriatic acid.
..... of sal ammoniac	Ammoniac.
..... of vitriol	Sulphuric acid.
..... of wine	Alcohol.
Spiritus rector	Aroma.
Sublimate, corrosive	Corrosive muriate of mercury.
Sugar of lead	Acetate of lead.
Sulphur, alkaline liver of	Sulphuret of potass, soda, &c.
.... metallic liver of	Alkaline sulphurets containing metals.
Tartar	Super-tartrate of potass.
..... emetic	Antimoniated tartrate of potass.
..... vitriolated	Sulphate of potash.
Tartars	Tartrates.
Tinctures, spirituous	Resins dissolved in alcohol.
Turbith mineral	Yellow oxide of mercury by the sulphuric acid.
Verdegris, or rust of copper exposed to the air	Green oxide of copper.
.........of the shops	Acetate of copper mixed with oxide.
.... distilled	Crystallized acetate of copper
Vinegar, distilled	Acetous acid.
.... radical	Acetic acid.
Vitriol, blue or Roman	Sulphate of copper.
...... green	.... of iron.
...... martial	.... of iron.
...... white	.... of zinc.
Vitriols.	Sulphates.

Old Names.	*New Names.*
Water, aërated or acidulated	Water impregnated with carbonic acid.
..... hepatic	Water impregnated with sulphuretted hydrogen.

To the preceding view of chemical nomenclature, the following explanations of terms will not perhaps be an unacceptable addition :

Calcination, applied to the metals, is their combination with oxygen, by means of heat.

Cementation, a process in which a body in a solid state, is surrounded by another in powder, and exposed for some time in a close vessel to a degree of heat which will not fuse either of the bodies. Iron thus surrounded by charcoal is converted into steel; and copper by cementation with powdered calamine and charcoal is converted into brass. The powder used in this process is called the *cement*.

Concentration, the separation and evaporation by heat of some or all of the watery particles of any fluid; by which the fluid is said, in common language, to become stronger or less diluted.

Crucible, a vessel usually made of clay, employed as a melting-pot for metals or other substances.

Cupel, a crucible made of burned bones, in which the precious metals are melted with lead. The lead is converted into glass, and passes through the vessel, carrying the impure metals along with it, and leaves the gold or silver in a state of purity.

Crystallization, is when a body passing from a fluid to a solid state assumes a regular form. Water always combines with salts in their crystallization.

Decantation, the separation of a fluid from the solid or undissolved particles which it contains. This is done by leaving the fluid at rest in a conical vessel, and when the foreign matter has deposited itself at the bottom, the fluid is gently poured off, in order to disturb the sediment as little as possible. When the matter deposited is light, and apt to mix with the fluid, or when the vessel containing it cannot be conveniently moved, a siphon is employed to draw it off. A thick woollen thread steeped in the liquor, and inclining over the edge of the vessel, makes a very good siphon for this purpose.

Decoction, a fluid holding in solution some substance which

it has obtained by boiling: thus we say a decoction of bark, &c. When the preparation is made by cold water it is called an *infusion*.

Decomposition. The substances of which any compound body is formed, are called its component or constituent parts, and when these are separated from each other, the body is said to be decomposed, or to have undergone decomposition. Thus soap is compounded of oil and an alkali, and when the oil and alkali are separated from each other the soap is decomposed.

Decrepitation, the small and successive explosions which take place in many chemical operations, as when salts are exposed to heat.

Deliquescence, the state of a salt which becomes fluid by its absorption of moisture from the atmosphere.

Desiccation, (drying,) the expelling or evaporating of humid matter from any substance, by means of heat.

Detonation, an explosion caused by the sudden expansion and combustion of certain substances; it differs from decrepitation in being more rapid, and louder.

Digestion, the slow action of a solvent upon any substance, whether assisted by heat or not.

Distillation, the separation by heat of a volatile fluid from other substances which are fixed; or the separation of substances more or less volatile from each other.

Effervescence, the bubbling and noise produced by the escape of volatile parts from a fluid.

Efflorescence, the conversion of a salt into powder, by the loss of its water of crystallization.

Eliquation, an operation in which a substance is separated from another which is less fusible, by the application of a degree of heat which will fuse only the former: thus copper may be separated from its alloy with lead, by a degree of heat which is sufficient only to melt the lead.

Extract, the solid matter obtained by evaporating the watery parts of a decoction or infusion.

Fixed, an epithet descriptive of such bodies as so far resist the action of heat as not to rise in vapour. It is the opposite of volatile; but it must be observed, that the fixity of bodies is merely a relative term, as an adequate degree of heat will dissipate all.

Fulmination, a still more violent and sudden explosion than detonation.

Incineration, the burning of vegetables, for the purpose of obtaining their residuum, which is lixiviated.

Lixiviation, the application of water to the fixed residues of

bodies, for the purpose of extracting the saline parts, which dissolve in the water, and afterwards crystallize on evaporation.

Menstruum, the fluid in which a solid is dissolved.

Oxidation, or *oxygenation*, or *oxidizement*, the combination of any one body with oxygen.

Precipitation, the effect which takes place when any matter held in solution by a fluid is caused to fall down in a concrete state, in consequence of the fluid particles combining with another. The product is called a *precipitate*, and the body added to the solution, in order to obtain it, is called the *precipitant*. The precipitate is not always composed entirely of matters held in solution by the fluid before the precipitant was added to it, but it often contains a part of the precipitant itself. Thus if to a solution of gold in nitro-muriatic acid, be added a solution of tin in the same acid, a precipitate is obtained which is composed of both gold and tin.—When the matter which falls down from a solution, is not formed in less than several hours or days, the word precipitate is changed for that of *deposition*.

Re-agent, a body which is brought in contact with another, to promote the separation of its principles or constituent parts. Re-agents are the immediate means of precipitation. They are sometimes called *tests*.

Rectification, the purification of a fluid by a second or reiterated distillation.

Reduction. When a metal is converted into an oxide by its combining with oxygen, it loses its metallic properties, and assumes the appearance of an earth; but when the oxygen with which it is combined is taken from it, all its properties as a metal are recovered; in this case the metal is said to be *reduced*, and the operation by which it is effected is called *reduction*. Revivification is a word used in the same sense as reduction, but is most commonly employed where mercury is the metal employed.

Residuum, (formerly called *caput mortuum*,) that part of a body which remains after the more valuable part has been separated by combustion, distillation, or sublimation.

Roasting, a preliminary operation, which prepares mineral substances for undergoing a series of succeeding ones, dividing their constituent particles, volatilizing some of their principles, and thus, in a certain degree, altering their nature. Ores are exposed to this process, with a view to separate the sulphur and arsenic which they contain, and to diminish the cohesion of their particles. Capsules of earth or iron, crucibles, and roasting pots, are the vessels in which it is usually performed; and the ore is generally exposed to the access of

external air. Sometimes, however, the operation is performed in close vessels; and two crucibles, luted mouth to mouth, may be employed on such occasions. Roasting is synonymous with *torrefaction* and *ustulation*.

Saturation. Most bodies which have a chemical affinity for each other, will only unite in certain proportions. When, therefore, a fluid has dissolved as much of any substance as it is capable of dissolving, it is said to have reached the point of saturation. Thus water will dissolve one-quarter of its weight of common salt, and if more salt be added, it will sink to the bottom in a solid state. Some fluids will dissolve more of certain substances when hot than when cold. Thus water, when hot, will dissolve a much larger quantity of nitre than when cold.

Solution, the dispersion of the particles of a solid body in any fluid, in so equal a manner, that the compound liquor shall be perfectly and permanently clear and transparent. This takes place when the particles of the fluid have an affinity or elective attraction for the particles of the solid. When solid particles are only dispersed in a fluid by mechanical means, it is mixture, not solution, and the compound is usually opaque and muddy.

Stratification, an operation in which bodies are placed alternately in layers, in order that they may act upon each other when heat is applied to them. It is nearly the same with cementation, but cementation is more particularly applied to the cases already noted.

Sublimation is to dry matters, what distillation is to humid ones. It is the process by which the volatile are separated from the fixed parts of bodies, by the application of heat alone, without moisture.

Volatilization, the reducing into vapour, or the aëriform state, such substances as are capable of assuming it.

Way, dry. When the chemist decomposes substances by the agency of heat, he is said to operate in the *dry way*.

Way, humid. When the decomposition is produced by water or other fluids, the effect is said to be produced in the *humid way*.

Of Chemical Attraction or Affinity.

The phenomena depending upon the attraction of gravitation, of cohesion, of electricity and magnetism, have successively been developed in the course of this work.

Of all these species of attraction, it has been seen that the attraction of gravitation is the most general and uniform. As far as human investigation extends, it appears to be exerted on every equal particle of matter in an equal degree, and consequently upon all aggregates, in exact proportion to the quantity of matter they contain. Its action also prevails at all distances, and is entirely independent of the state or nature of materials.

The attraction of cohesion, on the contrary, takes place only at minute distances; it differs greatly in degree between different substances, and between some substances it is not exerted at all. The solidity or hardness of substances is supposed to depend upon the strength of the attraction of cohesion between their particles, because the stronger this is, the more it opposes the disunity of the body. This species of attraction is often called the *attraction of aggregation*, because it simply tends to unite the particles of the same or different bodies into a mass, without any power to render the mass homogeneous. Capillary attraction, it has been observed, is merely a branch of the attraction of cohesion. See vol. I, p. 275.

Magnetic attraction is of a very partial nature; it is exerted only upon a very few substances, and by these substances only upon each other.

All bodies are capable of exerting electrical attraction, but they must in the first place, according to the view which the present state of knowledge affords of the subject, be either over or under saturated with a principle called the electric fluid.

It is not known whether all these kinds of attraction result from principles essentially different, or are different modifications of the same cause. All that can be affirmed of the state in which the ultimate particles of matter exist, is only the result of conjecture, and therefore all that can be said of the affections of these particles, must be equally liable to uncertainty. Yet whilst we admit that it answers a useful purpose to make a difference where a difference appears, generalization ought to be aimed at, where the facts will warrant it, because nature accomplishes an infinitude of effects by the agency of few principles. Perhaps chemical attraction, when thoroughly understood, will not be found essentially different from the attraction of aggregation.

The species of attraction called *chemical attraction*, is also not unfrequently designated by the appellation of the *attraction of composition*, or *chemical affinity*. This kind of attraction takes place only between the elementary particles of different bodies; and every integrant part of the compound which results from its effects, differs in its properties from any of its component parts. It is by this change of properties, that chemical combination, or the action of chemical attraction, is distinguished from mere mechanical mixture. By mechanical mixture, it is obvious, that gold, however minutely divided, could not exist in every part of a fluid lighter than itself; but when the fluid has a chemical attraction for gold, the solution is homogeneous, and incapable of separation by the filter, or any other mechanical means.

Every body differs in the degree of its attraction or affinity for the substances with which it unites, and when two bodies will not unite, it is for want of this affinity between their particles. When any two bodies have the same degree of attraction for all others, the chemist considers them to be identical. It is by the difference of affinities, that all the changes of nature and art are produced. In order to bring affinity fully into action, it is in general necessary that one or both of the bodies presented to each other should be in a fluid state; or that heat should be applied to disunite the particles, by lessening the attraction of cohesion; for mechanical subdivision or comminution never extending to the separation of the ultimate particles of bodies, seldom allows that liberty of action, in the exercise of which affinity appears. Instances, however, occur, in which the mixture of two solids produce a fluid: thus, if pounded ice and muriate of soda be mixed together, a fluid brine will be obtained, unless the temperature, at the time of the experiment, is lower than that at which brine freezes, and as this point is thirty-eight degrees below the freezing point of water, it does not occur in this country.

Dr. Black discovered that whenever a body changes its state by chemical affinity, its temperature is changed at the same time, either lessened or increased.

The discoveries of Sir H. Davy seem to establish as a fact, that no chemical affinity takes place between the particles of bodies, unless they be in an opposite electrical state; and that by artificially changing the electrical state of bodies, their affinities may be modified or destroyed.

The action of the affinity of composition, in different cases, has been distinguished in the following manner:

1. When two principles, united together, are separated by means of a third, we are said to have an example of *simple*

affinity. This simple affinity, Bergman called *single elective attraction*, an expression still much used by chemists.

2. When a body, composed of two others, cannot be destroyed by a third or fourth body separately applied, yet is destroyed or decompounded by the action of the third and fourth bodies, if these be united before they are added to it; the example in this case, and when any greater number of bodies are employed, is called *compound affinity*, or *compound elective attraction*.

3. When two bodies which have no perceptible action on each other, unite by the addition of a third body, the example is called *intermediate affinity*. It is instanced in the union of oil and water, by means of an alkali.

Tables of elective attractions have been constructed, which are of singular service in directing the attention of the chemist to the effects of substances on each other; we shall advert to them when we have considered the properties of the substances themselves.

Whatever relation the attraction of gravitation may have to the attraction of cohesion, the attraction of cohesion appears to be nearly related to chemical attraction, which appears to be only a more refined degree of it, and the electric fluid performs an important part in creating the difference.

The meaning of the term affinity being understood, the study of the chemist might be expressed by calling it the study of affinities. It is a more extensive knowledge of affinities, of which he is continually in search, and he can only improve by the institution of experiments, and a careful attention to his inferences.

We must now turn our attention to the chemical laboratory, in order to take a view of the means employed, to lessen, increase, or otherwise modify the affinities of bodies, in order to obtain them in a state of purity, to separate the simple from the compound, or to complete the combination of different bodies. Most of these effects are produced by the management of heat.

Of Chemical Operations and Utensils.

Crucibles and Cupels.

These are the vessels commonly employed to contain the bodies submitted to the action of artificial heat.

Crucibles are employed in the melting of metals, and other operations of fusion. They are made, for low heats, of earthenware or porcelain, but for strong heats, of clay and sand, or clay and powdered plumbago. Hessian and Dutch crucibles, which are made of refractory clay and sand, are generally the most approved; but modern chemists have an invaluable acquisition in platina, which metal is often made into crucibles, and will bear, without fusion or injury, a greater heat than any other known substance.*

Crucibles are generally made of the shapes shewn at figs. 1, 2, and 3, pl. I. Fig. 1, is a round crucible, with its cover and stand; fig. 2, a triangular crucible on its stand, suitable in operations where any thing is to be poured out; fig. 3, the form of a crucible used for assaying, and fusing ores in small quantities.

Fig. 4, is a cupel; these vessels are broad and shallow, because their contents must be exposed to a current of air. They are formed of bone-ashes, with a small quantity of clay and plumbago in powder.

Muffles.

In cupellation, it is necessary for the contents of the cupel to be exposed to the access of air; the cupel must not therefore be used in a closed furnace, or be surrounded with fire. A kind of small ovens are therefore employed, which are called *muffles*, see fig. 5. They are made of the same materials as crucibles, and the cupel being put into them, they are exposed to the heat of the furnace. They are also used in enamelling, and other operations, where heat is required, while the contact of the fire must be kept off.

Retorts.

Retorts are globular vessels, formed with a long neck, and are made of earthenware, glass, or metal, according to the use for which they are designed. They are used in distillation. When the retort is formed as represented at fig. 6, it is called a simple retort; when it has an opening at *a*, as in fig. 7, it is

* Cary, mathematical and philosophical instrument-maker, in the Strand, London, sells platina at 17s. 6d. per ounce, and makes but a small additional charge for the trouble of manufacturing.

called a *tubulated* retort. This opening is convenient for charging it. The conical tube of a retort is usually called its beak.

Glass retorts should be very thin, and of a uniform substance in every part, otherwise, from the inequality of their expansion, they will crack with the application of a very slight heat: they cannot also be exposed to the fire, unless defended by a coating, which is generally some earthy composition. Chaptal particularly recommends, for this purpose, fat earth which has been suffered to rot some hours in water; it must then be kneaded with horse-dung, and formed into a soft paste, which must be equally spread over every part of the retort to be exposed to the fire. The adhesion of this coating is such, that should the retort crack during the operation, the distillation may still be carried on. The retorts used over a lamp are not coated.

Cucurbits or Matrasses.

Cucurbits, or matrasses, are glass, earthen, or metallic vessels, usually of an oval or egg-shape, and open at the top They are used for the purposes of digestion, evaporation, solution, &c. One of these vessels is represented at fig. 8. A Florence flask makes a good matrass.

Alembics.

The alembic is used for distillation, when the products are of too volatile a nature for the use of the retort. It is nothing more than a matrass with a capacious head fitted to it, and from the head proceeds a tube or beak, like that of a retort. It is represented at fig. 9. As the external circumference or base of the head *f*, is lower than the beak, the vapours which rise and are condensed against its sides, first run down into the channel formed by the depressed part, and thence are conveyed off by the beak. The alembic is a more complex instrument than the simple retort, which with care will answer as well, except perhaps for matters which are partly converted into vapour, and partly sublimed; in which case the sublimed part is very conveniently retained by the head.

Receivers or Recipients.

A receiver or recipient is a vessel, usually of glass in small operations, for receiving the volatile product from a retort or alembic, to the extremity of the beak of which it is secured by luting in the manner shewn at figs. 10 and 11, where A and B are the receivers. Those receivers, which, like A, are made of a globular form, are often called balloons.

When it is required to have the receiver at a greater distance from the fire, than the length of the beak of the retort will allow, the connection is formed by means of one or more tubes called *adopters*, see fig. 12.

For the preparation of the luting, by which retorts, receivers, and adopters, are made air-tight, refer to the article of lutes and cements.

Evaporating Vessels.

These are made of wood, glass, metal, porcelain, or Wedgewood's ware. Those of the last mentioned composition are very convenient, as they are, like glass, easily kept clean, and are not very subject to crack by changes of temperature. They are generally in the form of shallow basins, and when the matter deposited in them would be apt to burn to the bottom, and be injured, if not strictly attended to, they are placed over the fire in a vessel filled with sand, which is then called a sand-bath. When even this heat would prove too great, the heat of boiling water is used instead of sand, and the evaporation is then said to be performed in *balneum mariæ.*

The Pneumato-chemical Apparatus.

When any permanently elastic gas is the product of distillation, and it is desired to fill receivers with this gas, without admitting the admixture of atmospheric air, it is obvious that the ordinary mode of connecting the receiver and retort will not answer. For this purpose then, the pneumato-chemical apparatus is employed, by which the purpose is effected with great facility. L, fig. 13, pl. I, is a vessel containing a narrow shelf, at the distance of three or four inches from its upper edge; and filled with water till the shelf is covered to the depth of an inch, at least. The shelf is perforated with a number of small holes, to which funnels are adapted on the under side. The glas jar, or receiver N, is now completely filled with water, and in this state, with its mouth downwards, it is placed upon the shelf over one of the holes. In this situation it remains full of water, from the pressure of the atmosphere, agreeably to the principles of pneumatics.

The materials from which the gas is to be disengaged, must now be put into a retort. If this retort be of earthenware, or iron, it may be heated in the wind furnace, or a strong fire; but when it is known that a moderate heat will set the gas at liberty, a glass retort, and the lamp-furnace, will afford a more agreeable mode of operation.

At the commencement of the process, the extremity of the retort, or of the tube luted to it, may be put under water, and it will be known when its contents have begun to act on one another, by

the bubbling which ensues. A few of the first bubbles may be allowed to escape, because they consist chiefly of the atmospheric air enclosed in the retort; but when they become numerous, they may be considered as the product of the chemical operation going on, and the extremity of the retort should be immediately placed under that funnel over which the mouth of the jar filled with water has been set. The bubbles will then pass through the funnel, and by their levity ascend to the top of the jar, where they will displace their bulk of water. Supposing the retort to contain a sufficient quantity of materials, the water will soon be entirely discharged from the jar, which will then be in appearance empty, but in reality is filled with the gaseous product of the operation. By keeping the mouth of the jar under water, the gas will be prevented from escaping, and by slipping the first jar aside, or directing the beak of the retort to another funnel, the jar above it may be filled in like manner.

The gas may be transferred from the jar N to any other, in the following manner: fill with water the vessel which is to receive the gas, and place it over a funnel, or hole on the shelf, in the manner a jar is placed. Then take the jar N, and sink it perpendicularly in the water, with its mouth downwards, till it is near, but rather lower than the edge of the funnel; now direct its mouth up the funnel, and depress the upper part of it towards a horizontal position, and its contents will escape into the vessel intended to be filled. In short, the very same position that allows a bottle (said to be empty because filled only with air) to fill with water, when held under that fluid, will allow the gas from the jar N to escape into another held above its aperture.

It will be obvious, that the cistern L need be nothing more than a common tub, or any earthenware vessel of sufficient size, across which a shelf can be fixed; but the cisterns used by lecturers are generally made of japanned tin-plate or copper, which have the advantage of being neat and light.

Some kinds of gas are absorbed by water; in obtaining them, therefore, by an apparatus on this principle, particularly if the quantity of the product is required to be ascertained, mercury is used instead of water. When this fluid metal is employed, the cistern is made of the smallest dimensions possible: fig. 14 is a section, and fig. 15, a plan of a mercurial cistern. The space A is for the immersion of the jar, which, when filled, is raised and placed upon the ledge, where the mercury is extremely shallow. C is the retort, and the process is every way the same as already stated, except that mercury is used instead of water: two grooves, *b b*, retain the shelf upon which the jar rests in filling. This shelf is got into its place by means of a wider part, seen at P in the plan, fig. 15. Troughs for holding mercury are made of iron, wood, or stone.

A small glass vessel, P, fig. 13, is used for measuring gases: by successively filling and inverting this vessel under a large jar, it is easy to throw into the jar as many measures of any gas as may be required.

To the extremity of the retort employed in obtaining gases, a crooked tube W, fig. 16, is luted; for the more readily bending over the edge of the cistern, and directing the effluent gas into the jar upon the shelf. If the beak of a retort be long, it may be so placed as to convey the gas into a jar, without the use of a tube of this description; but when the matrass, fig. 8, is used instead of a retort, the bent tube is indispensable.

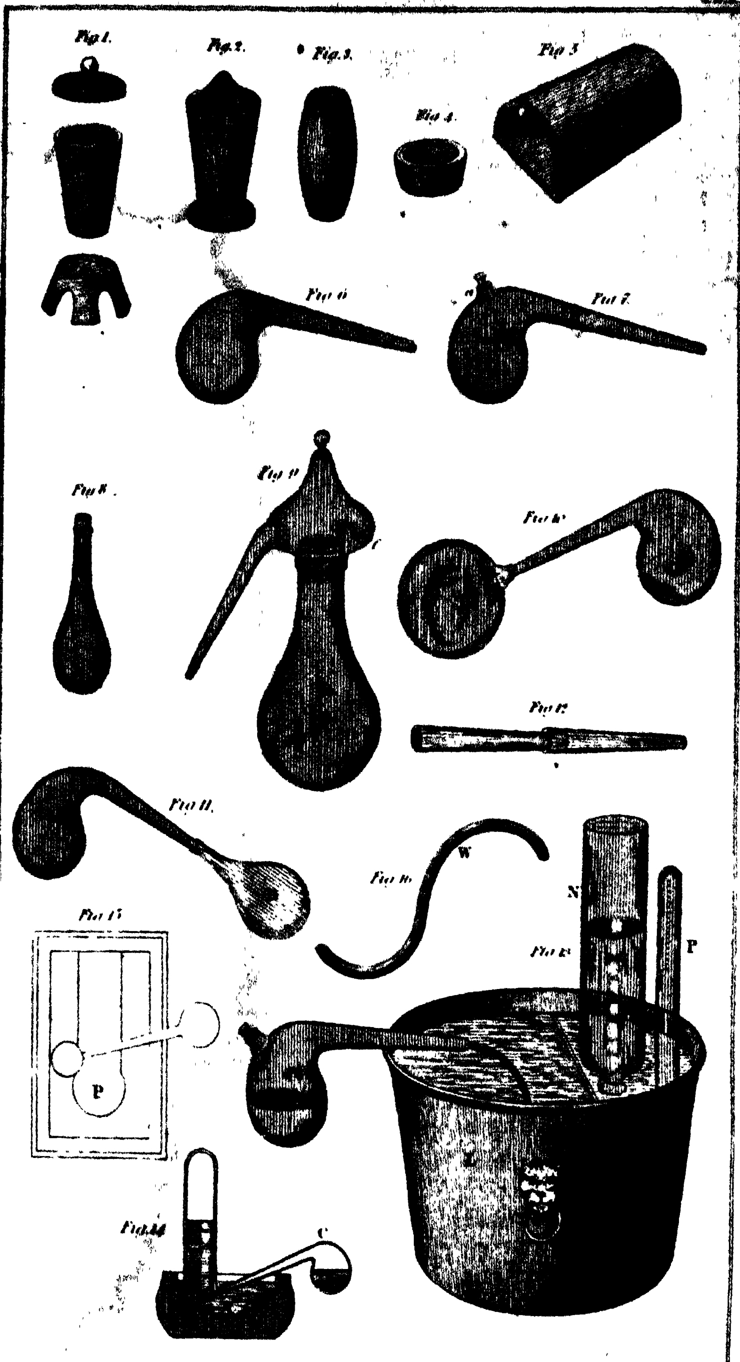
The Gazometer.

Vessels purposely constructed for the retention of gas, and for facilitating the drawing of it off as wanted, are called *gazometers*. They are much varied in their construction, but those on the principle we shall now describe, are amongst the most simple, and answer perfectly well: A B, fig. 1, pl. II, is a cylindrical vessel of glass, or japanned tin-plate, nearly filled with water, and having a tube C in the middle, open at the top, and branching, to communicate with the cork D. Within this vessel there is another cylindrical vessel, F, generally of glass, open at the bottom, which is inverted and suspended by the lines *e e*, which go over the pulleys *ffff*, and have weights, *g g*, attached to them, to balance the vessel F. While the stop-cock D remains shut, if the vessel F be pressed downwards, the air included within it will remain in the same situation, on the principle of the diving-bell; but if the cock be opened, and the vessel F be pressed down, the air included within it will escape through the cock, and if a blowpipe be attached to this cock, a stream of the gas may be thrown upon lighted charcoal or any other body. By means of the graduated rod *h*, the quantity thrown out is exactly ascertained; this rod being so divided as to express the contents of the inner vessel in cubic feet.

This instrument also answers for breathing any of the gases, by applying an ivory mouth-piece to the cock, and closing the nostrils. To render it more portable, the weights *g g*, are sometimes included in the uprights *i i* which are made hollow, and of a size sufficient for that purpose. Sometimes also there is another branch from the bottom of the pipe, in the middle, directed to the side of the outer cylinder and coming upwards by the side to the top, where there is another cock attached.

When it is required to transfer the gas from the gazometer into a jar, the crooked tube W, fig. 16, pl. I. may be adapted to the cock D, and the jar, previously filled with water, should be held under that fluid, to receive it in the same manner as if it were received from a retort.

CHEMISTRY.



Woulfe's Apparatus.

For those distillations which evolved so large a quantity of subtile, elastic, and often incondensible vapours, that no single receiver would contain them all, it was usual for the early chemists to have the upper parts of the retorts drilled, and a small stopper applied to the hole, which was opened occasionally for the escape of the vapours that could not be retained without endangering the retort: but by this precaution, the certainty of avoiding an explosion was not secured, because the exact time of the rapid disengagement of vapour could not be known, while a great loss, often of the most valuable part of the products, was unavoidably sustained. To prevent this loss and risk, an apparatus, invented by Glauber, but improved by Woulfe, whose name it receives, is employed; in this contrivance, a series of bottles or jars, communicating with the receiver, and with each other in succession, receive the volatile products; and each jar contains a quantity of water, in which the tube that brings the vapour terminates. By this means, all the vapours which water will condense are retained, and those which are of a different description, escape by an opening at the termination of the row of bottles. This apparatus, in its original form, was difficult to put together; several improvements of it have therefore been proposed, of which the following is the valuable one by Dr. Hamilton: A, fig. 2, pl. II. is the retort, fitted by grinding into a plug or piece B, represented at *b*, which last is also fitted by grinding into the neck of a globular receiver C. The use of the additional piece *b*, is to afford a due inclination to the retort, by an obliquity of its perforation or hole; instead of allowing it to remain horizontal, as it would if fitted to the hole in C, and also to facilitate the grinding in of a new retort in case of breakage. The piece *b* has a stopper *a*, which can be put in whenever the retort is taken out, whether for weighing or for any other purpose. The first receiver C, has a smaller neck opposite to B, which is ground into a corresponding neck of D, the second receiver, which last is tubulated, and has a tube H, open at both ends, ground into its vertical neck for the purpose of permitting absorption, and re-acting by its contents against the force required to protrude any gas through the bended tubes IKL. Every one of the range of receivers, EFG, has also two necks, by which they are successively fitted to each other, and each interior neck has a small tube fitted into it, which, by its curvature, reaches nearly to the bottom of the liquid (usually water) placed in each. By this disposition, the first product of condensation is generally re-

ceived in C, and the purer vapours proceeding to D, are in part condensed by the water placed therein, and are partly urged through the tube I, into contact with the water in E; and whatever may escape condensation in E, will be urged through the tube K, into the liquid in F. In this manner the operation may proceed through the whole set of vessels, till the incondensable vapour or gas shall pass into one of the inverted jars at P, which are filled with water, and have their mouths below the surface of water in the dish at the end of the series, precisely in the same manner as permanently elastic gas is collected by the pneumato-chemical apparatus. When these jars are filled, others are successively put in their place.

Of Furnaces.

Furnaces are of two kinds; viz. *blast-furnaces* and *wind-furnaces*, which are again subdivided into species, and distinguished generally according to the use which is made of them. Blast furnaces are urged by the air forcibly driven from bellows or cylinders; wind-furnaces by the draught of air arising from atmospheric pressure.

The furnaces employed for the purposes of a particular manufacture are of course adapted in size and construction to their specific application: of these it would be useless to give the particular details; but the practical chemist, who has all kinds of operations to perform, often in quick succession, requires a single furnace or two by which he can obtain all degrees of possible heat, and adapt without difficulty to all his views. We shall therefore describe the furnace of Dr. Black, who took much pains to construct a furnace of extensive utility, taking care at the same time to keep simplicity and economy in view.

In Dr. Black's furnace, see figs. 3, 4, and 5, pl. II. two thick iron plates, above and below, are joined by a thinner plate forming the body of the furnace, which is of an oval form. The upper part is perforated with two holes; the one A, pretty large, which is the mouth of the furnace, and which is of a circular form; and the other behind it, B, of an oval form, and designed for fastening the end of the vent, which is screwed down upon it. The undermost thick plate has only one large circular opening, L, fig. 5, toward the side of the ellipse, where the round hole in the top is placed: so that a line passing this circular hole has a little obliquity forwards.

The ash-pit, HH, fig. 4, is likewise made of an elliptical form, and a little widened, so that the bottom of the furnace is received within the ellipse. A little below, there is a border CE, that receives the bottom of the furnace; and except the holes of the damping plate DD, the parts are all closed by

means of soft lute, upon which the body of the furnace is pressed down; by which means the joining of the two parts, and of all the different pieces, is made quite tight; for the body, fire-place, ash-pit, vent, and grate, are all separable from one another. As the furnace comes from the workman, the grate F, fig. 5, is made to apply to the outside of the lower part. It consists of a ring laid on its edge, and bars likewise laid on their edges: and from the outer ring proceed four pieces of iron, by means of which it may be screwed down; so that it is kept out of the cavity of the furnace, and preserved from the extremity of the heat. Thus it lasts much longer, and is indeed hardly liable to any decay; for by being exposed to the air, it is kept so cool, that it is never hurt by the heat of the fuel. The sides, which are made of plate iron, must be luted within, to confine the heat, and to preserve them from its action.

Fig. 5, is a section of the furnace: ABC, the luting; DE and FG, oval plates of iron at the top and bottom; L the aperture over the grate above the ash-pit; O the passage from the body of the furnace, which is gradually curved downwards; the fuel is put in at the aperture K, to which a pipe is adapted for increasing the draught of the chimney.

This furnace may be adapted to the various operations of chemistry: for a melting furnace it is very convenient; we need only provide a cover for the opening above, which is made the door, and which, being immediately over the grate, is convenient for introducing the substances to be acted upon, and for allowing us to look into the vessel and take it out. This cover may be a piece of tile, or two bricks rendered flat and square: Dr. Black commonly used a kind of lid, with a rim containing a quantity of lute. To augment the heat, we may increase the height of the vent. It can be employed in most operations in the way of assaying; and the situation of the door allows us to see the substances very readily. It does not admit the introduction of the muffle; but can be employed in all those operations where the muffle is made use of; and in Cornwall such a furnace is made use of for the assaying of metals. To preserve the substance from the contact of the fuel, they cut off about a third of the length of a brick, and then put it in on one end, on the middle of the grate. They use the fuel in large pieces, that the air may have free passage through it, and open a little of the door, which occasions a stream of air to flow in; and this strikes upon the substance, and produces the effect desired; so that it may be used in the calcination of lead, to convert it into litharge. It also answers well in operations for producing vapour. To employ

it in distillations which require an intense heat, an earthen retort is to be suspended by means of an iron ring having three branches standing up from it, fig. 6, and which hangs down about half a foot from the hole, so that the bottom of the retort rests upon the ring, and is immediately hung over the fuel; and the opening between the mouth of the furnace and retort, is filled up with broken crucibles and potsherds, which are covered over with ashes that transmit the heat very slowly; by this means it answers for distillations performed with the naked fire.

Dr. Black sometimes caused this furnace to be made with a hole in the side, from which the neck of the retort may be made to come out; and in this way he distilled the phosphorus of urine, which requires a very strong heat.

For distillations with retorts performed with the sand-bath, there is an iron pot, fig. 7, adapted to the opening of the furnace, which is set on and employed as a sand-pot. The vent of the furnace then becomes the door; and it answers very well for that purpose, being more easily kept tight than if it was in the side, and in other respects is found more convenient.

In like manner this furnace answers well for the common still, which may be adapted to it: part of it being made to enter the open part of the furnace, and hang over the fire; and the vent becomes the door by which fresh fuel may be added. It is, however, seldom necessary to add fresh fuel during any operation. In the ordinary distillations it is never necessary; and even in distilling mercury, phosphorus, &c the furnace generally contains enough to finish the operation; so effectually does its construction preserve the heat from unnecessary dissipation.

For luting this and other furnaces, Dr. Black found nothing preferable to a simple mixture of sand and clay. The proportions for standing the violence of fire, are equal parts of sand and clay; but when designed for lining the furnaces, he used six or seven parts of sand to one of clay. The sand settles into less bulk when wet, and does not contract by heat, which it also resists as well as the clay itself. Besides this outside lining next the fire, Dr. Black used another, to be laid on next the iron of the furnace, and this consists of clay mixed with a large proportion of charcoal dust. It is excellent for confining the heat, and is put next the iron to the thickness of an inch and a half. That it may be rather dry when first put in, three parts by weight of charcoal dust, and one of common clay, must be mixed together when in dry powder, otherwise it is very difficult to mix them perfectly. As much water is

added as will form the matter into balls; and these balls are beaten with a hammer, till very firm and compact, upon the inside of the furnace. This luting, after being dried and gradually heated, acquires a degree of hardness equal to that of freestone, and proves very lasting.

The bars of the grate should be triangular, flat sides of which should form the bottom of the furnace within, and when of a large size, they are less liable to melt if made hollow.

Dr. Kennedy found that the greatest heat of a wind-furnace is within two or three inches of the grate. This distance therefore must be considered as the most proper for a crucible.

The height of the chimney has an important effect on the draught of a wind-furnace, because the longer the column of rarefied air it contains, the more the air presses towards its base to restore the equilibrium, consequently the greater the quantity of air which passes through the furnace in a given time, and the more rapid the combustion of the fuel.

The common furnace becomes a reverberatory furnace when it terminates at the top in a dome; in consequence of which form, when a retort is placed within the furnace, the concavity of the dome reflects the heat strongly upon the upper side of the retort, which is thus heated more equally than if it merely rested on the fire. The furnaces of glass-houses are of this description, and the same construction is also in use upon a small scale by chemists, as it is very useful in distillations.

Charcoal is the fuel most commonly employed in small furnaces; it has the advantage of producing a strong heat, and as there is no flame, the heat is much confined to the body of the furnace, while the absence of smoke prevents the chimney from being choaked. It is, however, expensive, and is consumed with rapidity; charred coal or coke, may therefore be used instead of it; this fuel is less expensive than charcoal, not only in the cost of an equal measure, but in the rate of its consumption, which is slower; it also affords a stronger heat. Where a uniform but not very intense heat is required over a considerable surface, coal is proper, from the flame it affords; it is by choice much used in reverberatory furnaces, and for distillations.

The Lamp Furnace.

This name is given to the apparatus in which an Argand's lamp is employed to furnish the heat required. It is shewn at fig. 8, pl. II. An upright stem, A, is attached to a broad and heavy base F. The lamp B is affixed to this stem by a sliding socket, and can be fixed at any height by the screw L, at the back of the socket. The wires CD are in the form of a ring, and are fixable in the same manner as the lamp, by screws *m n*. This is a very convenient apparatus for experiments upon a small scale, whether in distilling, subliming, evaporating, or melting substances not very refractory. It will also give a considerable heat to a small sand-bath, the vessel for the sand being made of thin copper. The retorts or other vessels employed are placed upon the ring C, and supported, when necessary, by a string or wire from the ring D. Another stem G is often employed, as the most convenient mode of supporting the receiving vessel. Thus in the figure, an intermediate receiver, H, conveys the products from the tubulated retort I to the bottle M. The same stem may often be made to support both retort and recipient, as XY.

The Blowpipe.

The blowpipe, see fig. 9, pl. II, is a brass tube by which the flame of a lamp or candle may be directed upon any substance to be operated upon. It is generally held in the mouth, and blown through by the breath. The bore is not more than one-eighth of an inch at the end F, held in the mouth, and at the other end next the flame it is seldom required of a greater diameter than will admit a pin. It is, however, usual to have several pieces to screw upon the extremity R, containing apertures of different sizes. A small bowl or cavity S, is usually formed in the instrument, to receive and condense the vapours of the breath.

Those who use the blowpipe, soon acquire the necessary art of maintaining a continual stream of air through it for several successive minutes. This is effected by breathing through the nose, while the blowpipe is supplied by the breath in the mouth. To do this, the tongue must be applied to the roof of the mouth, so as to interrupt the communication of the mouth with the passage to the nostrils during the time of breathing.

The candle or lamp used with the blowpipe should have a thick wick, which should be snuffed clean, and bent a little forwards in the same direction as the passage of the breath.

If the aperture next the flame be round and smooth, and not too large, the flame will be of a neat conical shape, and blue colour, at the extremity of which the heat is strongest.

The substances to be acted upon by the blowpipe, are generally bedded in hard charcoal, unless of such a nature that they would sink into and blend with this material. When charcoal, therefore, is improper, a metallic spoon, as of copper, silver, gold, but especially of platina, may be used. The substance acted upon should not in size exceed a pepper-corn; and when it is refractory, a flux may be used.

The advantage of the blowpipe consists in the facility with which the heat may be produced, the rapidity of the whole operation, and the changes effected being open to ocular inspection. To increase its utility, the object has been to render the exertion of blowing by the mouth unnecessary; the vapour from alcohol has even been used instead of air; but the simplest contrivance consists in the use of bladders, from which the air is driven by the pressure of a weight, and which may be replenished by bellows at another aperture; this second aperture should be covered by a valve opening inwards. With a contrivance of this kind, oxygen gas may be employed instead of common air, by which all the effects of the instrument will be prodigiously increased.

The Thermometer.

The thermometer is a well-known instrument for measuring the actual or relative temperature of bodies. Its properties are dependent upon the disposition of all bodies to acquire an equal degree of sensible heat or cold, and on the effects of heat in expanding some substances, the changes of the dimensions of which are examined by a scale of equal divisions. Mercury expands by heat and contracts by cold with greater uniformity than any other known fluid; it is, therefore, the most proper and the most commonly used for thermometers, which are constructed in the following manner:—

The first requisite is a glass tube, which may be obtained at a glass-house. Its bore should be perfectly equal, and in diameter proportioned to the size of its intended bulb: if the tube be not thicker than a common goose-quill, a bore of one-twenty-fourth of an inch, and a bulb of half an inch in diameter, will be proper. The uniformity of the bore may be ascertained, by dipping the tube into a bottle of mercury, then closing the upper orifice with a finger, by which means the mercury that has entered the tube may be drawn out with it. Now place the tube in a horizontal position, and by inclining

it more or less, make the column of mercury occupy every part of the tube in succession. If the mercury, in all parts of the tube, is of the same length, which may easily be known by a pair of dividers, or by two marks made on a piece of paper, at a distance from each other equal to the length of the mercury at one station, the tube may be considered fit for use: if it will not bear this trial, it should be rejected, for though the divisions of the scale might be regulated so as to balance the irregularities of the tube, the trouble of doing this with precision would be considerable. A suitable tube being selected, one extremity of it may be heated, by the lamp and blowpipe, till it is soft enough to be hermetically sealed, which is accomplished by touching it with another piece of tube, twisting it, and drawing it out. A larger portion of the extremity must now be softened, when it may be expanded into a bulb by forcibly blowing into the tube at the other end. Another and more easy mode of producing the bulb, consists in tying the aperture of a small Indian rubber bottle to the end by which the air is forced in; a slight pressure of this vessel, when the other end is soft, will instantly attain the object, with the great advantage of avoiding the introduction of moisture into the tube.

The mercury with which the bulb and tube is to be filled, should be boiled and purified as if for a barometer, (see page 27.) In mercury thus prepared, immerse the open end of the tube, in a position as nearly horizontal as possible; heat the bulb at the same time, and the air in the cavity of the glass being thus rarefied, a part of it will be driven out through the mercury, a quantity of which will immediately rise by the pressure of the atmosphere, and occupy its place. Still keep the open end of the tube immersed as before stated, and heat the bulb till the mercury in it boils; then let it cool, and it will be found completely filled. It will be proper, however, once or twice more to repeat the boiling of the mercury, and it may then be considered as sufficiently dry. For the final boiling, after the tube has been filled with mercury, a piece of paper should be rolled about the upper end of it, and tied on, in such a manner that it may form, above the end of the tube, a cavity which will serve to retain the boiling metal till it subsides. The bulb, when heated, should be turned round by moving the tube between the fingers, to make it uniformly hot, but an empty part of the bulb should not come in contact with the flame, lest it should be melted. A small wax candle affords the clearest and most suitable flame for this operation.

The next point to be attended to is the graduation of the scale. It is sufficiently obvious, that the indications of the thermometer are merely of a comparative nature; we know nothing of the absolute degree of caloric in any body; but it answers the purpose of graduation, and suffices for the uniformity and comparison of different instruments, if any two points of invariable temperature can be obtained. To these two points any two different numbers may be affixed which may be thought eligible; and these being determined upon, it follows that equal spaces above and below them will be the measure of equal differences of temperature. The standard temperatures desired, remained unascertained till the time of Newton, who fixed upon the temperature of freezing and of boiling water, and all subsequent philosophers have acceded to the propriety of his choice. Water always freezes at one uniform temperature, and boils at another, allowing it to be pure, and in the latter case, that the atmospheric pressure, or height of the barometer, is the same in all the experiments. Fahrenheit called the temperature at which the water freezes, 32 degrees, and the temperature at which it boils 212 degrees; consequently the space between these points contained 180 degrees. It is this graduation which is commonly used in this country; and which we intend for the instrument in hand.

Take the thermometer, which is yet open at the end, and full, or nearly so, and plunge the bulb into water just beginning to freeze, or into melting snow. The point to which the mercury subsides, will shew the freezing point, or 32 degrees, and the height of this point from the bulb will render it easy to estimate whether the divisions will be large or small. If the instrument is intended chiefly for measuring the lower degrees of heat, it will be proper to leave the freezing point rather high, as for example one-third of the length of the tube above the bulb; but if intended chiefly to measure the higher degrees of heat, as from a summer-heat to that of boiling water, or still higher, the freezing point must of course be fixed low accordingly. To fix the freezing point at the proper height, it will be necessary to drive some of the mercury out of the tube, which is easily done by warming the bulb; care should, however, be taken to expel too little rather than too much at a time, to spare the hazard of its requiring to be again filled.

The thermometer is now ready for sealing, which must be done in such a manner as to exclude, totally if possible, the atmospheric air from the tube. The first step is, to heat and draw out the tube a little, till the bore is so fine at its extremity as scarcely to be visible; in this state, it may be sealed in an instant. Now heat the bulb by one candle, while the

extremity of the other end is near another candle; the mer cury will rise, and as soon as a drop of it appears as if ready to fall out, the candle by which the bulb is heated should be withdrawn, and by the use of the blowpipe the other extre mity should at the same moment be sealed.

When the mercury has subsided, the sealed end may be strengthened by holding it again in the flame, and rounding it.

The operation having been well conducted, the mercury will freely slide backwards and forwards in the tube on changing its position.

The thermometer may now be adapted to its scale, in order to obtain the exact points by which the other degrees may be known. In the first place, it is immersed in melting snow, and when the mercury appears to be stationary, its height should be marked, and will be the freezing point. In determining the boiling point, the water should be pure, for if it contain any mixture that increases its density, it will acquire a greater than the common boiling point of water; fresh rain-water, or the water of clean melted snow, may be considered sufficiently pure. Another particular to be regarded is the atmospheric pressure; for the greater this is, the greater the heat which the same water will acquire before it boils, that is, before it is converted into steam: the Royal Society have determined to take the boiling point when the barometer stands at 29-8 inches, and a better authority cannot be followed. In this state of the atmosphere, therefore, the thermometer should be immersed in the steam arising rapidly from boiling water. The vessel containing the water should be covered, but the cover should contain two holes, one for the exit of the steam, and the other for inserting the thermometer up to the place where it is likely to require marking.

Two determinate points having been now ascertained, the whole scale may be divided with ease, for by dividing the space between the freezing and boiling points into 180, the size of the degrees will be obtained, and the division may be carried as far above and below these points, as the length of the tube admits.

That point in the scale of a thermometer from which the enumeration commences, and which is marked with a cipher, (0) is called the zero of that thermometer. From the zero, thermometers are graduated both upwards and downwards, unless so constructed that the zero is at the bulb. To express the numbers below the zero, the sign of subtraction or minus is prefixed, thus 20° degrees below the zero is written—20°. Fahrenheit, supposing he had produced the greatest degree of

cold possible, by the mixture of snow and salt, made the point at which the thermometer then stood the zero, or the point which denoted the entire abstraction of heat; and the distance between this point, and the height of the mercury in the freezing mixture, being divided into thirty-two parts, the boiling point was of course 180 degrees higher up. But the idea of Fahrenheit, with respect to the greatest degree of cold, is entirely fallacious; we shall shortly have occasion to shew that much higher degrees of cold may be produced than he obtained; but here we shall only observe, that Crawford, Irvine, and others, consider the real zero in respect to cold to be at least 1200 degrees below the freezing point of water.

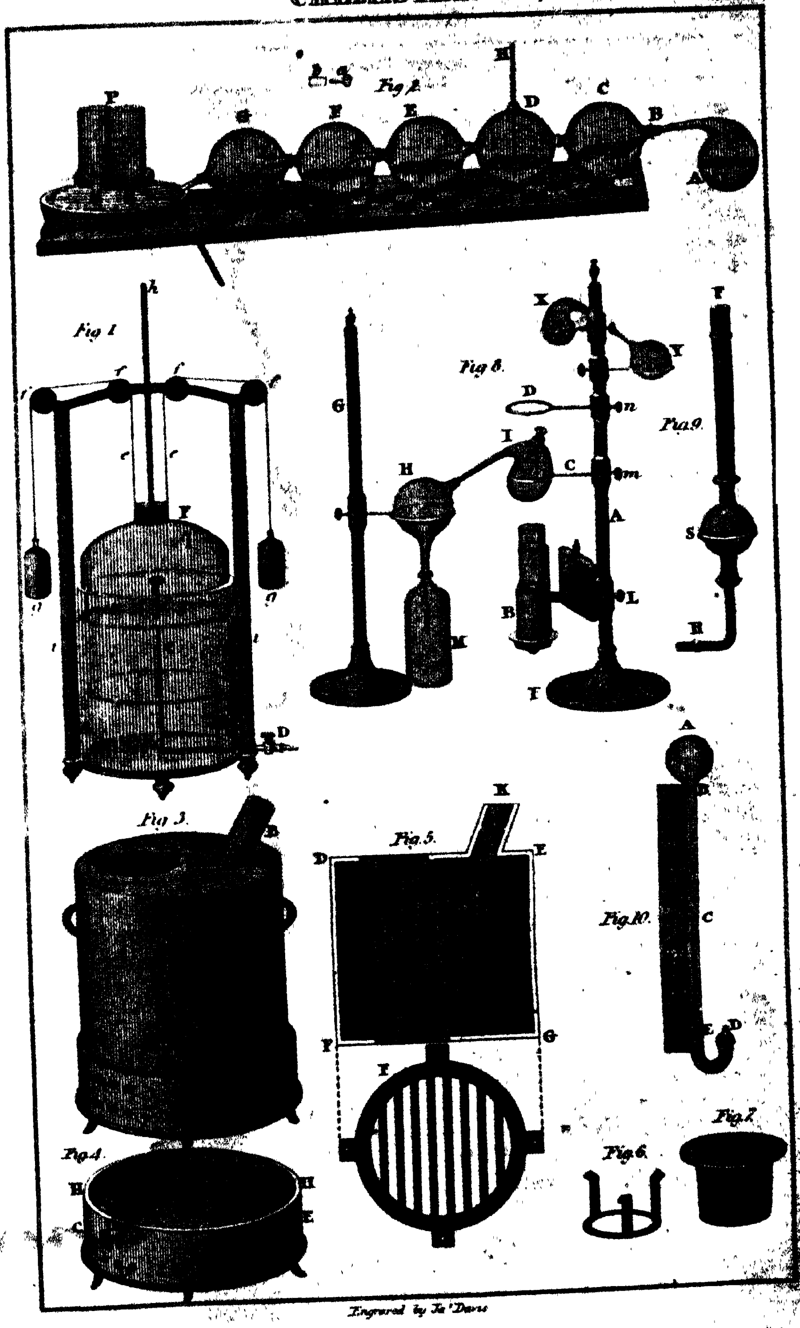
As the real zero of cold is unknown, the zero of the scale of many thermometers in use begins differently. There are three thermometers besides Fahrenheit's employed in the different countries of Europe, viz. Reaumur's, Celsius', and De Lisle's. Reaumur's thermometer was generally used in France before the revolution, and is still much used in other parts of the Continent. The freezing point, in this thermometer, is marked zero, and the boiling point 80°. To convert the degrees of Reaumur's thermometer into those of Fahrenheit, multiply them by 9, divide that product by 4, and add 32. Thus if the degree of Fahrenheit corresponding to 20 of Reaumur be required, the formula will be $20\times9\div4+32=77°$ of Fahrenheit.

The thermometer of Celsius, used in Sweden, and also in France, where it is called the centigrade thermometer, has the zero at the freezing point like Reaumur, but the space between this point and that of boiling water is divided into 100 degrees. To convert the degrees of this thermometer into those of Fahrenheit, the process is the same as before, except that the divisor must be 5 instead of 4. Thus, to reduce 20 of its degrees to those of Fahrenheit, the formula will be $20\times9\div5+32=68$. When the degrees are above the boiling point in these thermometers, 212 must be added instead of 32.

The only two fluids generally used for thermometers, are mercury and alcohol, each of which has its advantages. Of all fluids, mercury is the most sensible to heat and cold; and the most readily freed from air. It is easily made pure, and when pure is always of the same density. It sustains a heat of upwards of 600° of Fahrenheit's scale, and does not become solid, until cooled down to 39° or 40° below 0. With these properties, it becomes admirably fitted for thermometers intended for general purposes. Alcohol has the advantage of expanding six times as much as mercury by the same acces-

sion of heat; and it bears a greater degree of cold without congelation, than any fluid adapted to this purpose. Its disadvantages are, that it is difficult to obtain it always of the same degree of strength, and it is converted into vapour at a heat much less than the boiling point of water. When alcohol is used, it is tinctured with cochineal, that the space it occupies in the tube may be more readily seen.

Air is one of the most expansible fluids, and it was the first fluid employed to form a thermometer. Air thermometers are still in use, and are constructed as follows: a glass tube, BE, fig. 10, pl. II, is connected at one end with a large glass ball A, and at the other end immersed in an open vessel, or terminating in a ball DE, with a narrow orifice at D, which vessel or ball contains any coloured liquor that will not easily freeze. Nitric acid tinged of a blue colour by a solution of sulphate of copper, or spirits of wine tinctured with cochineal, will answer this purpose. But the ball A must be first moderately warmed, so that a part of the air contained in it may be expelled through the orifice D; and then the liquor, pressed by the weight of the atmosphere, will enter the ball DE, and rise, for example, to the middle of the tube at C, at a mean temperature of the weather; and in this state, the liquor, by its weight, and the air included above it in the tube and ball A, by its elasticity, will counterbalance the weight of the atmosphere. As the surrounding air becomes warm, the air in the ball and upper part of the tube, will expand and drive the liquor into the lower ball, and consequently its surface will descend; on the contrary, as the surrounding air becomes colder, that in the ball is condensed, and the liquor, pressed by the weight of the atmosphere, will ascend; thus the liquor in the tube ascends or descends more or less, according to the state of the air contiguous to the instrument. To the tube is affixed a scale of the same length, divided upwards and downwards from the middle, C, into 100 equal parts, by which means the ascent and descent of the liquor in the tube, and consequently the variations in the temperature of the atmosphere, may be observed. Air-thermometers are in general constructed so as to have a range equivalent to a few degrees of Fahrenheit: and they serve to shew slight changes of temperature in a very striking manner; on this account it is proper to have them in a laboratory, although they are upon the whole of limited utility.



Engraved by Ja's Davis

FISHER, SON & Co. LONDON, 18[illegible]

The Pyrometer.

As the common mercurial thermometer cannot be employed to ascertain degrees of heat above 500 or 550 degrees of Fahrenheit, it is totally inapplicable to most of the operations carried on in furnaces and ovens: yet in a variety of manufactures and chemical operations, success depends upon the adjustment of the heat with a degree of nicety which the most experienced persons are incapable of determining by mere observation. To supply this desideratum, Wedgwood contrived an instrument called a *pyrometer*, the range of which extends to 32,000 degrees of Fahrenheit's scale. Its utility is derived from the property which clay has of contracting in proportion to the degree of heat to which it is exposed. This contraction is permanent, and a less degree of heat than that which the clay has experienced, will not alter its dimensions. If, therefore, a piece of clay, of a given bulk, be exposed to the heat of a furnace, it may occasionally be taken out, and upon being applied to a gauge, the degree of its contraction may be ascertained, and consequently the greatest heat to which it has been exposed, provided this gauge has been graduated by previous experiments. Wedgwood constructed his pyrometer by duly availing himself of these circumstances.

The pyrometric pieces of clay intended to be used to any given scale, should be exactly of the same composition, as different clays contract in different degrees by the same heat. To guard against the disadvantage of a difference, Wedgwood offered to the Royal Society a bed of Cornish clay, sufficiently extensive to furnish the world with pyrometric pieces for ages.

The gauge for measuring the diminution which the pieces of clay suffer from the action of fire, is made of two pieces of brass, twenty-four inches long, with the sides exactly plane, divided into inches and tenths, fixed five-tenths of an inch asunder at one end, and three-tenths at the other, upon a brass plate; and the pyrometric pieces are made at first so as just to fit the wider end. The pieces of clay are generally made about one inch long, but if their breadth be just equal to that of the wider end of the gauge, viz. five-tenths of an inch, their dimensions in other respects are not material.

It is obvious that, in proportion to the shrinking of the clay by heat, it will slide farther and farther towards the narrow end of the converging scale, one side of which is divided into tenths of an inch, and every division, of which it contains 240, answers to a 600th part of the breadth of the little piece of clay. One degree of the pyrometer is equal to 130 degrees of Fahrenheit's scale.

Apparatus.—Pyrometer.*

The regular shrinking of clay by heat, does not commence at a lower degree than a red heat fully visible in daylight; and this heat is equal to 1077½ degrees of Fahrenheit, or about 500 degrees above the point at which the mercurial thermometer terminates. It becomes therefore desirable to measure the range of temperature to which neither of these instruments applies; but nothing has yet been contrived which answers the purpose in a simple manner.

The pyrometric pieces of clay should be exposed as nearly as possible to the same heat as the material, the heat received by which they are intended to measure. For this purpose, they are usually placed close to it, and in the same crucible, but when the contents of the crucible might adhere to them, they are enclosed in a small case, made of crucible clay; and as they may be reduced in any degree, while their breadth is retained, the pyrometric piece may generally be introduced without difficulty into any but very small crucibles, and they may be disposed by the side of very small crucibles, without much hazard of receiving their heat materially sooner, or with greater intensity than the contents of the crucible.

The pyrometric piece may be taken out of the fire during any period of the process, and instantly cooled in water, so as to be ready for measuring in the gauge in the space of a few seconds. It will not crack, expand, contract, or sustain any other injury; and may be immediately replaced in the strongest fire, to resume its office of indicating higher degrees of heat than what it has already been exposed to.

The following table will give a better idea of the heats designated by the pyrometer, than any general remarks:

	Fahr.	Wedgw.
Extremity of the scale of the pyrometer	32270°	240°
Greatest heat of an air furnace, 8 in. square	21877	160
Cast-iron melts	17977	130
Greatest heat of a common smith's forge	17327	125
Welding heat of iron, greatest	13427	95
Welding heat of iron, least	12777	90
Fine gold melts	5237	32
Fine silver melts	4717	28
Swedish copper melts	4587	27
Brass melts	3807	21
Heat by which enamel colours are burnt on	1857	6
Red-heat fully visible in daylight	1077	0
Red-heat fully visible in the dark	947	—1
Mercury boils	600	$3\frac{673}{1000}$
Water boils	212	$6\frac{658}{1000}$
Vital heat	97	$7\frac{542}{1000}$

	Fahr.	Wedgw.
Water freezes	32	$8\frac{12}{100}$
Proof spirit freezes	0	$8\frac{28}{100}$
The point at which mercury congeals, consequently the limit of mercurial thermometers, about	—40	$8\frac{48}{100}$

Wedgwood found by analysis, that the clav of which his pyrometer-pieces were formed, consisted of two parts of pure siliceous earth, to three parts of pure argillaceous or aluminous earth.

The use of the pyrometer shews in a remarkable manner the inaccuracy of the common mode of expressing the higher degrees of heat by estimation. Thus the heat at which copper melts is called a white heat, though it is only 27° of the pyrometer; the welding heat of iron, or 90°, is also a white heat; even 130°, at which cast-iron is in fusion, is no more than a white heat; and 160°, and upwards, is still a white heat. These examples shew very clearly that the temperature of bodies in furnaces is raised in a manner of which we can have no idea, unless the materials subjected to it are such as to give us the necessary information.

Miscellaneous Remarks on Apparatus.

The list of chemical apparatus might easily be enlarged, but it will be more advantageous to the memory, and perhaps more agreeable to the reader, to combine the description of apparatus of less general application than those already noticed, to the occasion for their use. Yet there are some articles which, under the present head, appear entitled to enumeration. It will be evident, that in a place where, as in a laboratory, all kinds of mechanical operations are occasionally resorted to, that a large strong table or bench is of considerable importance. Convenient small tables or blocks of wood should also be at hand, for supporting mortars, levigating stones, an anvil, &c. A large vice is also a machine of great utility, and the use of it almost necessarily implies that of hammers, rasps, files, saws, and other implements for working wood and metals.

Mortars, with their pestles, are made of iron for coarse purposes, and for dry and very hard matters; for other occasions they are made of glass, Wedgwood's ware, and agate. Levigating stones are best made of porphyry, but those of the hardest kinds of grit-stone, with a pebble muller, answer extremely well. With the mortar and levigating stone, a spring-knife is very useful.

Rods of glass, or porcelain, or even clean straws, are used for stirring mixtures in glasses and other vessels. Glass and metal spatulas should also have their place.

Unsized paper is employed for filtering, and when used is generally placed upon a funnel. A funnel, with fluted sides, is more convenient for this purpose than any other.

It is proper to have a pair of bellows, of the largest portable size; shovels, tongs, pokers, for managing the fire, are of course necessary; and tongs of different shapes, for taking out crucibles, muffles, &c. from the furnace, should also be at hand.

A plentiful supply of water, fuel, and other things of constant necessity, need scarcely be alluded to. Distilled water is to be used in analyses, and all operations which are to be conducted with exactness.

In such a place as a laboratory, where a vast variety of utensils are to be arranged, and where the eye ought to command the situation of every individual article, the arrangement should be such, as to be at once commodious and easily maintained. The rule, to let every article have one place, and but one place, is extremely simple, but if rigorously observed, it will introduce the most serviceable order; for whatever it may be that is only to have one place, the common desire to avoid wasting labour, will lead to the adoption of the most convenient one. For example, the mortars and sieves will not be far separated; and near the vice will be placed the hammers, rasps, files, and other tools used along with it. In making this arrangement, a liberal supply of shelving is necessary; but hooks driven into the wall, are in some cases equally convenient.

At the same time it must be observed, that it is injurious to the advancement of chemical knowledge, to give currency to the idea, that nothing can be learned or discovered, without the aid of an extensive and costly apparatus. Every chemist should himself be a good mechanic, and the resources of the mechanic who attends to his pursuits with his whole will, are often sufficient to enable him to accomplish very important ends at little expense, and by very simple means. It has indeed happened, that some of the most remarkable discoveries have been made by apparatus of this character. In simplifying the means of conducting an experiment, what is merely elegant and convenient, should be well separated from what is absolutely essential; for it sometimes happens, that nearly the whole cost of an apparatus is occasioned by some remarkably exact workmanship, which though it ensures an easy and regular performance, may be dispensed with in a single private experiment or two, without any real disadvantage. The pneumato-

chemical apparatus, for example, may be rendered handsome and costly, or it may be constructed as already intimated, very economically; indeed, with every absolutely essential property, almost without the expense of a shilling to most persons, by using for the moment such utensils as nearly every house affords. A common tub, as before observed, or any wide vessel capable of holding water, will serve for the cistern; a piece of any kind of board may quickly be placed in it, to form a shelf; a Florence flask will make an excellent retort, on this or any other occasion for which glass is proper; wine or porter bottles may be used as receivers, holes in the shelf, fitted with funnels, are unnecessary, as the bottles may receive the gas by allowing their necks to hang over the edge of the shelf; the bent tube cannot well be dispensed with, but the cost of it is very trifling, and it may be made out of a straight piece of glass tube, by the assistance of a blowpipe, or the dexterous use of a common fire, as the curve shewn in the plate is not the only figure that will answer; a zigzag figure nearly like the letter Z, will succeed perfectly well; even tobacco-pipes may be connected so as to answer the purpose.

In operations where a strong fire is requisite, a common culinary fire may be converted into a furnace, by placing a piece of sheet iron to close up the front above and on either side of the top bar, and even the whole front of the bars, if a stronger draught still be required; the effect may also be further aided by the use of a pair of portable bellows.

Where a very intense and long continued heat is not required, a tobacco-pipe may be used as a crucible; a china saucer makes a good evaporating vessel, and is not so liable to break as glass. The use of the blowpipe and the lamp-furnace are also attended with great economy, and little trouble, wherever applicable.

A common pair of bellows may at once be made to answer the purpose of a blowpipe, by fixing in or against the extremity of the pipe any piece of metal not easily melted, and in which a small hole can be pierced. If the pipe and lower handle of the bellows be tied down to the table, one hand will suffice to lift the other handle, and the upper side, left to its own fall, will drive the slender current very steadily to one spot; if a fresh supply of air be required, it may be obtained with a rapidity scarcely more disadvantageous than the inequality of the current from the mouth. A less quantity of air will in this way be efficient than when blown from the mouth; because the air from the lungs has lost the greater part of its oxygen, and it even contains carbonic acid gas.

By these, and a great variety of other resources, which are promptly suggested to the active mind, and which will be different with persons in different situations, a demonstration of all the principal facts of chemistry may be obtained, and new experiments carried into execution, in some instances without any real expense, and in general without much.

Of the Classification of Substances.

All the substances in nature, when classed according to their apparent or sensible properties, may be considered either as solid, fluid, aëriform, or ethereal. But they may be distinguished by any of these characters, and yet be either simple or compound; to follow, therefore, such a mode of classification, would not suit our purpose, as it would introduce the separate consideration of substances so closely allied as to be almost identical. We shall, therefore, adopt the more general division of bodies into simple and compound, commencing with those which deviate the farthest from the solid state.

Here it may be proper to explain in what manner chemists use the term simple. They do not mean by the term *simple*, that the body to which it is applied is absolutely known to be simple; but merely that it has never been decompounded, nor is known to be capable of decomposition. Hence a substance at this time called simple, may hereafter, by more improved modes of analysis, be proved a compound. What modern chemists call simple bodies, the ancient chemists call elements, a term which is yet sometimes used.

The combination of a substance with caloric or light, is not regarded as removing it out of the class of simple bodies, otherwise we could have nothing to denominate simple.

The substances here styled *ethereal*, are freqüently distinguished by the epithet *imponderable;* but as it is considered a rule which ought to be acted upon, to adopt no name which may induce false ideas, or is likely to prove unfounded, the latter term is open to objections from which the former is free; and, indeed, the impropriety of it seems decisively proved by the fact that at least one of the substances to which it is applied, is demonstrably subject to the power of gravity.

The arrangement we have proposed, introduces the following classification of simple substances:

Simple Substances

Ethereal.

Light, Caloric.

Aëriform.

Oxygen.

Aëriform and Combustible.

Nitrogen, Hydrogen.

Concrete and Combustible.

Carbon, Phosphorus,
Sulphur, Metals.

Of Light.

The mechanical properties of light have been discussed in relation to the science of Optics; its chemical properties are not less extraordinary.

Light has an influence upon almost all bodies which are exposed to it. It is the source of the colour of vegetables, and in a great measure, if not entirely, of their odour. Plants which grow in darkness are devoid of colour, in which case they are said to be *etiolated* or *blanched*. Gardeners avail themselves of this fact to render vegetables white and tender. Vegetables so situated, that the light can only fall freely on one side of them, gradually turn to the light, and chiefly shoot out in that direction. Some, whose stems are flexible, follow the course of the sun during the day, and always present the same face towards him.

The back, fins, and other parts of fish exposed to light, are coloured, but the belly, which is deprived of light, is always white.

The vegetable and animal productions of tropical countries, are distinguished by brighter and deeper colours than those of higher latitudes. The cause of this phenomenon must be referred to the greater abundance and intensity of the light, upon the action of which all colour is dependent. The superior strength of the perfumes, odoriferous fruits, and aromatic resins, of these countries, has the same origin.

All metallic oxides, but especially those of mercury, bismuth, lead, silver, and gold, become of a deeper colour by exposure to the rays of the sun; some of them become perfectly revived, others only partially. The yellow oxide of tungsten, if exposed to the light, loses weight, and becomes blue. Green precipitate of iron, exposed to the solar light, also becomes blue.

Light has a considerable influence on the crystallization of salts, many of which will not crystallize unless exposed to it. Camphor, kept in glass bottles exposed to light, crystallizes in symmetrical figures, on that side which is turned towards the light; and spirits of wine, water, &c. rising by insensible evaporation in half-filled vessels, constantly attach themselves to the most enlightened sides of the vessel.

It is not to be supposed that these effects are produced by the mere contact of light; on the contrary, we have abundant proofs that light has the power of entering into the composition of bodies, and of being afterwards extricated from them without any alteration. A great number of substances become luminous after having been exposed to light; a property rendered obvious by carrying them instantly from the light into the dark: the diamond is a body of this kind; indeed, if the human hand be thrust into a strong light, through an aperture in a perfectly dark room, it will, when drawn in, and the aperture closed, be plainly seen, although the other hand is totally invisible. In most bodies, this property is very evanescent, but some compositions have been discovered in which it possesses considerable permanency. Canton, to prepare one of them, directs common oyster-shells to be calcined in a good coal-fire for half an hour, and then the purest part of them to be pounded and sifted. Three parts of this powder are to be mixed with one part of the flour of sulphur, and rammed into a crucible, which must be kept red-hot for an hour. The brightest parts of the mixture are then to be scraped off, and kept for use in a dry phial well stopped. When this composition is exposed for a few seconds to the light, it will, on being carried into the dark, emit a sufficient light to distinguish the hour by a watch; and after it ceases to shine, this property is recovered by again exposing it to the light. Bodies possessed of this property, in an eminent degree, are called *solar phosphori;* and they are further distinguished by the property, that when they have ceased to shine in an ordinary temperature, they will, if heated, again emit light, although they have not been so situated as to imbibe a fresh supply. Solar phosphori are

vehicles in which light can be confined, and given out, after a considerable lapse of time, without changing the nature or temperature of the substance that retained it. Thus Du Fay exposed a diamond to light, and immediately covered it with black wax; he found on uncovering it at the end of some months, that it shone strongly in the dark.

Light is so constantly the attendant of combustion, that men can scarcely avoid the conclusion, of its being always a consequence of combustion. The phenomena of the solar phosphori seem to militate against this idea, as they take place in vacuo, where there is no air to maintain combustion. It is evident that the light extricated during combustion, must have previously existed either in the combustible itself, or in the oxygen gas, by which combustion is maintained. The most probable opinion is, that it exists in both the combustible and the oxygen; but facts favour the opinion, that the light furnished by the oxygen gas is not considerable. Those substances which combine with the greatest quantity of oxygen, during combustion, are not remarkable for giving out the most light, but rather the contrary; of which the combustion of hydrogen is an example. Hydrogen gas, in combustion, combines with more oxygen than any other body, but the light extricated during this process, is feeble. That the light afforded by oxygen is not the predominant source of supply, is also proved by the great diversity of the colours of the light given out by different combustibles.

All substances, except the gaseous and ethereal, become luminous, when heated to about 800° of Fahrenheit's scale, in which state they are said to be *red-hot*, and they continue to be luminous until their temperature is considerably reduced below 800°, whether supplied with oxygen or not; for a piece of iron wire becomes red-hot in melted lead.

Light has the power of disengaging oxygen from many of its combinations, besides those of metallic oxides alluded to above. Pure, pale nitric acid cannot be preserved but in bottles quite full, or in the dark; for light expels the oxygen, if there be any possibility for gas to escape, and renders the acid yellow. Vegetables are constantly exhaling oxygen during the day, and constitute one of the principal means by which the purity of the atmosphere is renovated.

In the solar spectrum, formed as described in treating of Optics, by allowing a ray of light to pass through a prism in a darkened room, heat and light are not present in correspondent degrees, those rays which illuminate the most, not being the

strongest in their heating power. The rays in the centre of the spectrum have the greatest illuminating power, as may be ascertained by viewing successively in each, a small body, such as the head of a common nail. It will be seen most distinctly in the light green, or deep yellow rays, and less plainly towards either extremity of the spectrum. If the bulb, previously blackened, of a small air-thermometer, be viewed in succession through the differently coloured rays, it will be found to indicate the greatest heat in the red rays, next in the green, and so on, in a diminishing progression, to the violet. When the thermometer is removed entirely out of the confines of the red rays, but with its ball still in the line of the spectrum, it rises even higher than in the red rays, and continues to rise till removed half an inch beyond the extremity of the red ray. Beyond the confines of the spectrum on the other side, that is, a little beyond the violet ray, the thermometer is not affected, but it is remarkable, that in this place there are invisible rays, which exert all the chemical effects of the rays of light, and even with greater energy. Light speedily changes from white to black the fresh precipitated muriate of silver. This effect is produced most rapidly by the direct light of the sun; and the rays, as separated by the prism, have this property in various degrees. The blue rays, for example, effect a change of the muriate of silver in fifteen minutes, which the red require twenty minutes to accomplish, and generally speaking the power diminishes as we recede from the violet extremity; but entirely out of the spectrum, and beyond the violet rays, the effect is still produced. Hence it appears that the solar beam consists of three distinct kinds of rays,—of those that excite heat, and promote oxydation; of illuminating rays; and of de-oxydizing rays. A striking illustration of the different powers of these various rays, is furnished by their effect on phosphorus. In the rays beyond the red extremity, phosphorus is heated, smokes, and emits white fumes; but these are presently suppressed on exposing it to the de-oxydizing rays, which lie beyond the violet extremity Gum-guaiacum is changed by light from a yellowish hue to green; and this change is, according to Dr. Wollaston, attended with an absorption of oxygen; yet guaiacum becomes green in the rays beyond the violet or most refrangible, and yellow in the least refrangible rays. This exception to the general effect of the rays beyond the violet, renders questionable the propriety of calling these rays de-oxydizing, although this term is most commonly applied to them.

Light and heat, from their general, and apparently intimate connection, have often been considered as the same substance in different states of intensity, but the separation in a great measure of the rays causing light, and those causing heat, in the above experiment, indicates a real difference in these principles. It is true, that there is none of the visible rays which are without the power of heating, but this may be owing to the imperfection of the mode of separation; Dr. Herschel concludes, from experiments, that the focus of heat falls at some distance from that of light. The contents of the next section will shew the difference between light and caloric in many other points of view.

Of Caloric.

That peculiar substance or property of bodies which produces the sensation of heat is called *caloric*.

Previous to the formation of the new nomenclature, the distinction between heat and its cause was found to be necessary, and therefore the cause was often called (as it is now sometimes) the matter of heat, or igneous fluid, or simple fire; but as caloric may be combined with bodies without producing the effects which we attribute to heat or fire, the new term became necessary, for the sake of greater precision; yet, to avoid the frequent repetition of the same word, heat, the effect, is often written for caloric, its cause.

If heat be an effect of caloric, it may be inquired, what is caloric itself? To this inquiry it must be answered, that it is not known whether it is a substance which has a distinct, independent existence, or, like gravity, merely a property of matter, and consisting in a peculiar motion or vibration of its particles. In proportion, however, as science has improved, the opinion which considers caloric as a real substance, has appeared so much more extensively consonant with the known facts, than any other, that it has continued to gain ground. It will be useful to adopt it in this place, as it coalesces so well with the language which must be used in treating the subject; yet we may observe, that whatever may be thought of the nature and essence of caloric, the narration of the facts which delineate its effects, may be perfectly well understood.

It may be proper to premise, that caloric exists in two states, in one of which it is called *latent* or *combined* caloric; in the other, *sensible* or *free* caloric. Latent caloric is in chemical union with the body in which it exists, and therefore,

however considerable in quantity, it makes no perceptible addition to the temperature of that body. Sensible caloric is that portion of caloric which affects the senses, and which the body will communicate to others of a lower temperature. Latent caloric may become sensible in a variety of ways, thus a bar of iron, taken cold, may be hammered till it becomes red-hot; and the mixture of different ingredients, at common temperatures, will often burst into a flame. The caloric extricated under these circumstances, certainly resided in the substances; but in its latent state, or until overcome by a superior affinity, it was inert as the acid in a neutral salt. When caloric becomes active or sensible, it always produces heat; when it becomes latent, it produces cold.

Caloric passes through all substances without exception. In this property, it stands alone; even light, the only other ethereal substance with which we are acquainted, passes through but a very small number of bodies; this is one, among the many reasons that increase the probability of their being distinct agents.

By the abstraction of a sufficient portion of caloric, all fluids become solid. Till lately, alcohol was supposed to be an exception to this rule, but it can now be frozen, which is only another name for such an abstraction of caloric as enables it to become solid. Solidity is, therefore, the natural state of all substances, and they become fluid only when the affinity between them and caloric is so great, that the caloric which pervades them, separates their particles and lessens their attraction of aggregation, in a degree that admits their easily sliding over each other. It is when this degree of attraction for caloric takes place, either at or below ordinary temperatures, that the term fluid is in common language more particularly used; at elevated temperatures most bodies become fluid, which is an additional proof of caloric being the cause of fluidity.

Fluidity is a medium between the solid and aëriform state. Fluids possess too small a portion of caloric to be perceptibly elastic; but gases, the solid particles of which are kept at a great distance, by the large quantity of caloric combined with them, are elastic in a high degree, and are therefore often called elastic fluids. Most of these bodies are said to be permanently elastic, because their attraction for caloric is so strong, that they cannot be procured alone in a concrete state; but the oxy-muriatic acid gas is an example of a gas which crystallizes, and is converted into a solid at about the temperature of freezing water; and that all the rest are capable of assuming a

concrete form, is an unquestionable inference from the fact of their entering into combination with solids. They combine with those solids for which their solid particles have a stronger attraction than for the caloric which retains them in the state of gas. A circumstance proving the large quantity of caloric combined with elastic fluids, is, that the condensation of them produces heat. An instance of this is shewn in the use of the pneumatic instrument for setting fire to tinder, see page 25.

The sensible caloric of adjacent bodies is incessantly employed in maintaining each other's equilibrium of temperature, the hottest always communicating its redundancy to those beside it. This propensity may be retarded, but it cannot be stopped; we possess no means of insulation by which a red-hot piece of iron, for instance, can be kept red-hot, except by constant or frequent contact with other red-hot bodies.

Caloric passes through different bodies with different degrees of facility or speed; those bodies through which it passes the most freely, are called good conductors; those through which it passes with difficulty are called bad conductors. The best conductors of electricity are, generally speaking, the best conductors of caloric; but as caloric pervades all bodies, it follows that there is no body which is a non-conductor of it.

A piece of iron and a piece of wood, after having been for some time exposed to the same temperature, indicate by the thermometer the same degree of heat, but upon taking them in the hand, the iron feels considerably colder than the wood. This is a deception; the iron is not colder than the wood; but we consider every thing we touch as cold or inclining to cold, which has not the same heat as the hand; and on the contrary, we consider every thing hot, or inclining to be so, the temperature of which exceeds that of the hand. The difference then between the wood and the iron consists in the rapidity with which the iron, from being an excellent conductor, carries off the heat of the hand to acquire the same quantity of caloric; whereas the wood is a bad conductor, and does not carry off the heat of the hand so fast as it is supplied by the animal functions, for which reason it excites no sensation of coldness. The softer the wood, the worse conductor it becomes. It is here supposed that the wood and iron are at a less degree of heat than the human body; otherwise the effects would be different; for if the wood and iron be put into an oven moderately warmed, after acquiring the heat of it, the wood may be held in the hand, although the iron cannot be endured, because different conductors impart caloric with nearly the same readiness or reluctance that they receive it.

Solid bodies are the best conductors of caloric, and among solids, the metals are pre-eminent, though not all alike. Dr. Ingenhouz procured cylinders of several metals exactly of the same size, and having coated them with wax, he plunged their ends into hot water, and judged of the conducting power of each by the length of wax-coating melted. From these experiments he concluded, that the conducting power of the metals which he examined were in the following order:

Silver,
Gold,
Copper, } nearly equal.
Tin, }
Platina, }
Iron, } much inferior to the others.
Steel, }
Lead, }

Next to metals, stones appear to be the best conductors of caloric, but they differ considerably from each other in this respect. Bricks are indifferent conductors. Glass is not a good conductor, which is the cause of its being apt to crack, when suddenly heated or cooled, the expansion in different parts being very unequal. The earthy coating which chemists apply to glass retorts, is serviceable in part by spreading more rapidly and uniformly the heat applied. Charcoal is a bad conductor; Morveau ascertained its conducting power to be, to that of fine sand, as two to three. The warmth of any article of clothing is proportionate to the slowness with which it conducts caloric. Hares' fur, beavers' fur, raw silk, wool, cotton, and linen, are distinguished by the slowness of their conducting power in the order enumerated, which designates their warmth as used for clothing. But the same material may be a better or worse conductor, according as its texture is more or less loose; fur, for example, contains a large quantity of air in its texture, which is a principal source of its warmth, air being an exceedingly imperfect conductor.

Count Rumford's investigations induced him to conclude that fluids are non-conductors of caloric. It may be inquired then, how the whole quantity of a fluid contained in a vessel can be heated, by the fire applied to one side of that vessel? This he explained by observing, that the particles of a fluid are perfectly at liberty to move among each other; that therefore the stratum of particles in contact with the heated side of the vessel, having been rendered specifically lighter by the caloric they have received, rise to the surface, and is succeeded by

another stratum of particles which rises to the surface in its turn. This intestine motion continues till the whole quantity of fluid has acquired a uniform heat, and thus the whole of it derives an extraordinary quantity of caloric from contact with a conductor, and not by communication from one part of itself to another. It has, however, been shewn, that this notion of fluids is not correct; although it is admitted that they are very bad conductors of heat, and that it is the ready motion among their particles which renders this property not very obvious. Gases are bad conductors in a still higher degree than common fluids.

There is no effect of caloric more universally exerted, than that of its dilating the bodies into which it enters. There are few exceptions to this rule, and some of the cases which appear such, cannot really be reckoned as exceptions; for example, those in which a body is decomposed, or something is separated from it. The pyrometric pieces of clay are instances of this kind; the more they are heated, the more they shrink in all their dimensions; but this is owing to the water which is separated from them, and which cannot be done without a very intense heat, the last portions of water separating with extreme difficulty. The case of water itself approaches more nearly to an exception to the rule; when ice is melted, it occupies less space than in its solid state; this is partly owing to the air-bubbles which it contains, and partly to the crystalline arrangement of its particles requiring more room than before. The expansion of water, by the loss of caloric, commences at 42.5°, and gradually increases till it is converted into ice. When heated above 42.5°, it expands like other bodies. Cast-iron expands as it undergoes the crystallization that converts it into a solid, which is the reason that it forces itself into every crevice of the mould, and forms excellent castings.

Gases are more dilatable than other bodies by a given increase of temperature; liquids rank next, and solids the last; but in each of these classes, there is considerable diversity. The expansion of atmospheric air is eight times greater than that of water, and the expansion of water is forty-five times greater than that of iron; the temperature of each substance being supposed to be raised from 32° to 212° of Fahrenheit. The expansion of bars of different metals by the same degree of heat, as taken by Ellicot's pyrometer, was as follows:

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	Lead.
73	103	95	89	60	56	149

If the rod of a pendulum be made of steel, General Roy found that its expansion by every four degrees of the thermome-

ter, will amount to a second per day, and yet we see by the above statement, that steel is one of the least expansible metals.

Different bodies require different portions of caloric to raise them to the same temperature; and in all cases the quantity of caloric required to raise any body to a given temperature, is called the *specific caloric* of that body; and the capacity of bodies for caloric is said to be greater or less, in proportion as their specific caloric is greater or less.

Equal quantities of the same fluid, at different temperatures, when mixed together, obtain a temperature which is a mean proportional between the two temperatures previous to the mixture. But as the capacity of water for caloric is three times greater than that of mercury for caloric, if an equal weight of these two fluids be mixed together, the temperature of the mixture will be greater than the mean temperature, if the water were the hottest of the two fluids at the time of mixture.

It is the extraordinary quantity of caloric which some bodies combine with, that causes their fluidity, and the quantity which they require for this purpose, is called the *caloric of fluidity*. Whenever, therefore, fluids become solid, their caloric of fluidity becomes sensible, and is employed in heating whatever it is in contact with. Thus when quicklime is quenched by water, a great heat is produced; this heat is from the water's caloric of fluidity, the solid particles combining with the lime, it becomes disengaged. The same phenomenon takes place in mixing water with plaster of Paris. If we take a mixture of ice and water, we shall find its temperature by the thermometer to be 32°. Let it be set in a proper vessel upon a hot fire, and it will be found upon repeated trials, that though a large quantity of caloric has entered the vessel, the thermometer will not rise higher than 32° until the last particle of ice has disappeared. The fact is, that the attraction of ice for caloric is greater than that of water for caloric, and therefore the water does not become hotter until the ice has regained the whole of its caloric of fluidity, after which it acquires heat in the usual manner.

Dr. Black proved by a very satisfactory experiment, that the quantity of caloric of fluidity is sufficient to raise the same quantity of water 140°.

But on the contrary, when solids become fluid, or when a compound is formed which has a greater attraction or capacity for caloric than its component parts before their union, the body feels extremely cold, until it has derived from other bodies the quantity of caloric it requires to saturate it. Thus a mixture of salt and snow becomes fluid, and sinks the thermometer to zero. Mixtures operating on this principle, and which

will sink a thermometer to the freezing point or lower, are called *frigorific mixtures.* Some mixtures of this kind have been discovered, which produce an astonishing degree of cold; an extensive table of them has been published by Walker, in the Philosophical Transactions, from which we shall select the most remarkable:

Table of Freezing Mixtures.

Ingredients.	Parts of each.	Thermometer sinks.
Muriate of ammonia Nitre Water	5 5 16	From 50° to 10°.
Muriate of ammonia Nitre Sulphate of soda Water	5 5 8 16	From 50 to 4.
Sulphate of soda Diluted nitric acid	3 2	From 50 to 3.
Sulphate of soda Muriatic acid	8 5	From 50 to 0.
Snow Common salt	1 1	From 32 to 0.
Snow or pounded ice Common salt	2 1	From 0 to —5.
Snow or pounded ice Common salt Muriate of ammonia and nitre	1 5 5	From —5 to —18.
Snow or pounded ice Common salt Nitrate of ammonia	12 5 5	From —18 to —25.
Snow and diluted nitric acid		From 0 to —46.
Snow Diluted sulphuric acid Diluted nitric acid	2 1 1	From —10 to —56.
Snow Diluted sulphuric acid	1 1	From 20 to —60.

The acids employed in these freezing mixtures operate by causing a rapid solution of the salt. It appears by experiments made subsequently to the above, that caustic potash and muriate of lime produce a greater degree of cold than any other bodies. Two parts of the first should be mixed with three of the latter. The use of these salts has this further advantage,

that they may be restored after an experiment, to their solid state by evaporation. Five pounds of muriate of lime will freeze thirty-five pounds of mercury.

The salts employed in forming freezing mixtures should be newly crystallized, and reduced to fine powder just before they are used. The snow should be that which has recently fallen, light and dry. The vessels employed for the mixture should be very thin, and the ingredients should be mixed together thoroughly and with celerity.

Salts deprived of their water of crystallization produce heat instead of cold, and the reason for using them fresh, is, that they may contain the greatest possible quantity of the water of crystallization.

When deprived of the water of crystallization, the salts produce heat, because part of the water is converted into a solid state, but when containing this water, it produces cold by the quantity of caloric it requires for its caloric of fluidity.

The tendency of caloric to maintain an equilibrium, indicates that its particles are repulsive of each other. Caloric has indeed been supposed to be the only repulsive power in nature, and therefore the cause of repulsion in whatever form it presents itself; hence caloric may be the cause that the particles of bodies are never in absolute contact, because they attract a certain quantity of it with greater force than their own particles.

It has been ascertained by a great number of ingenious experiments, that the more bodies are heated, the less they weigh, and *vice versâ*, the colder they can be made, the heavier they are. This fact appears to disfavour the hypothesis that caloric is a real substance, but it has been well accounted for on the principle of repulsion. Bodies which are extremely hot, must repel each other, and be repelled by the earth, more than those which are cold; hence their gravitation must be in some degree diminished, which is equivalent to stating that they weigh less than at other times.

If a bar of iron, or any other good conductor, be heated in the middle, and placed in a horizontal position, each end will become equally hot in the same time; but if the bar thus heated be placed vertically, the upper extremity will acquire a greater and more lasting heat than the lower one. It appears then that caloric has a constant tendency to ascend; a property which we may expect, if the preceding position be true, that it is repelled by the earth. It is to this ascending power of caloric, that a quantity of ice placed on the surface of a vessel of hot water presently melts; but if confined at the bottom, the period of melting is delayed in the proportion of one to eighty. For this

reason when steam is employed to heat water, it should enter at the bottom, and when to heat rooms, the pipes should be horizontal.

Caloric is reflected from bright and shining bodies, apparently with the same regularity as light. A piece of iron, heated in so low a degree that no light radiates from it, even in a dark room, if set in the focus of a concave metallic mirror, will reflect the radiating caloric to another mirror of the same sort placed opposite, and a piece of phosphorus, placed in the focus of the second mirror, will be consumed. The temperature of the mirrors is not increased during this operation; the whole of the incident caloric appears therefore to be reflected. If glass mirrors be employed, the phosphorus will not be kindled, but the caloric will be employed in raising the temperature of the glass.

Probably the sun is the sole original fountain of caloric, as of light, but when we consider the supplies obtained by abstracting caloric from its combinations, it is specified as derived besides from the following sources: combustion, percussion, friction, and the mixture of different substances. The facts relative to friction are not the least curious. Count Rumford having fitted up an apparatus for the purpose, found that a blunt borer, pressing with a force equal to 10,000 pounds avoirdupois, upon the bottom of a hole in an iron cylinder 7¾ inches in diameter, and 9 8/13 inches long, after making 960 revolutions, at the rate of 32 in a minute, caused a heat at the bottom of the hole that raised the thermometer from 60° to 130°. The quantity of metallic dust or scales produced by this friction, amounted to 837 grains. Now if we were to suppose that all the caloric was evolved from these scales, as they amounted to just 1/948 part of the cylinder, they must have given out 948°, to have raised the cylinder one degree, and consequently 66,360°, to raise it 70°, or to 130°, which is certainly incredible. To examine the subject further, the cylinder and borer employed in this experiment were included in 18.77 pounds avoirdupois of water. At the commencement of this experiment, as in the former one, the thermometer was at 60°. After the cylinder had revolved for an hour, at the same rate as before, the temperature of the water was at 107°; in 30 minutes more it was at 178°; and in two hours and 30 minutes, the water actually boiled. According to the computation of Count Rumford, the caloric produced would have been sufficient to heat 26.58 pounds avoirdupois of ice-cold water boiling hot; and it would have required nine wax candles of a moderate size, burning with a clear flame all the time the experiment lasted, to have produced as much heat. In this experiment, all access of water into the hole of the cylinder, where the friction

took place, was prevented. But in another experiment, when the water was allowed free access, the result was the same. Experiments more decisive of the large quantity of caloric evolved by friction, can scarcely be desired; but there are other proofs of the same fact, abundantly familiar to all, in rubbing together different substances. It is well known, that two dry pieces of soft wood, rubbed hard together for some time, will take fire, and that carriage wheels sometimes take fire by the friction of the axle-tree on the nave. In all these and similar cases, the question is, whence does the caloric rise? This difficulty has never been solved; but Count Rumford was induced to conclude, from his experiments, that caloric was not a real substance, but a *peculiar kind of motion;* yet as all other phenomena are consistent with the material existence of caloric, and as the accumulation of caloric by friction is far from shewing the actual existence of it to be impossible, this opinion can only be considered as gratuitous. Dr. Thomson suggests, that an agent well known to be evolved by friction, and which, producing many of the phenomena of caloric, is doubtless combined with it, may be concerned in the present case. This agent is electricity; but the conjecture can only be duly appreciated by the light of future investigations.

No body has been found that will not admit of variations of temperature, and as this susceptibility clearly indicates their union with caloric, which cannot take place without they have an affinity for it; it may, therefore, be concluded, that all bodies have an affinity for caloric. This affinity or union, is always, or at least in general, of a chemical nature, for it is attended with the grand characteristic of chemical union, viz. it destroys the identity of the ingredients. Water is not more changed by the addition of different doses of an acid, than bodies by the addition of different quantities of caloric; although small alterations in either case escape observation. In extreme cold, steel becomes nearly as brittle as glass; and all the metals lose their malleability; it is to caloric then that malleability is owing; thus by a large addition of caloric, iron becomes soft, and by a further addition still, it becomes fluid. Upon this and similar bodies, caloric alone produces no further change; but water, after having been rendered fluid by it, is by a certain further addition converted into steam or vapour, which possesses the power of indefinite expansibility by further additions of caloric. The same kind of expansibility distinguishes all other elastic fluids, which are solid bodies in union with caloric. Hence it must be obvious how much is required to be done, to ascertain the effects of

caloric in all their diversities; and it adds prodigiously to the variety of cases which occur in researches on this subject, that the affinities of caloric are the weakest of all that are known to exist.

OXYGEN.

Oxygen is the name given to the solid particles of oxygen gas, which is a combination of oxygen, caloric, and light, and is the simplest form in which oxygen can be obtained. Oxygen is called the radical or base of the gas; and the same mode of expression is used in other cases.

Oxygen gas was discovered by Dr. Priestley, on the 1st of August, 1774. It is invisible, perfectly elastic like common air, and possesses neither taste nor smell. It is 740 times lighter than water. Its weight to atmospheric air, is as 1103 to 1000.

Oxygen enters into chemical combination with a great number of substances, in which it exists in a concrete or solid state; it is by the application of heat, or of acids, to some of the substances containing it, that we usually procure it in the form of gas. Ingenhouz obtained from four ounces of nitrate of potass, melted with a little slacked lime, 3000 cubic inches of this gas. Let any quantity of this salt be put into an earthen or iron retort, to the extremity of which is adapted a bent tube, terminating in the pneumatic trough. The retort must be gradually made red-hot, when the oxygen gas will be rapidly disengaged, and will be very pure. An old gun-barrel, with the touch-hole riveted up, is often used instead of a retort; only a small part of the lower end of the retort is filled with the nitrate of potass. In the use of a gun-barrel, there is some danger of an explosion, which often occurs unexpectedly, some time after it has been taken from the fire, if the residuum be disturbed in attempting to clean the tube. Retorts used in this experiment, are cleaned with difficulty.

When considerable quantities of oxygen are acquired, the black oxide of manganese is most frequently used, as it is the cheapest article that can be employed, and supplies the gas in a good degree of purity. The manganese is put into an iron retort, which is made red-hot, and the gas is collected by the pneumatic apparatus, as in using nitrate of potass. One pound of the best manganese will yield upwards of 1400 cubic inches of the gas. The retort is easily cleared of the manganese when the experiment is ended; and if the manganese that has been once used, be exposed for some time to the air, it will serve again; but the cheapness of the article renders this of little consequence.

If diluted sulphuric acid be added to manganese, a glass retort may be used, and the heat of an Argand lamp will be sufficient to disengage the gas in abundance.

Red oxide of mercury, and of lead, yield oxygen in the same manner as manganese.

Oxygen gas may also be obtained with the greatest facility and purity, from hyper-oxy-muriate of potass. A small retort must be partly filled with this salt, and exposed to the heat of a lamp; the salt melts, and oxygen is extricated in abundance, as it is held by this singular substance in a state of great concentration, and by a very weak affinity.

Oxygen may likewise be obtained from the green leaves of plants: a bell-glass, or receiver, filled with water, is inverted on a dish of the same fluid; some fresh green leaves are introduced under the glass, and the whole apparatus is set in the direct rays of the sun; oxygen gas is disengaged from the leaves, and rises to the top of the jar. This is too tedious a process for supplying a quantity of oxygen, but it shews the effect of the rays of light on vegetables.

Atmospheric air contains about twenty-two parts in the hundred of oxygen gas, and it is remarkable, that this proportion is very nearly the same in all situations;—in the most crowded city and on the open plain, in the deepest valley and at the greatest heights. The importance of it will appear obvious, when it is observed, that animals cannot breathe, without destruction, any air or gas which does not contain oxygen; that they cannot live without air, nor can they live if obliged to breathe the same air for any length of time. The reason is, that the oxygen in air is, in respiration, absorbed by the animal system, and when the quantity of it contained in any portion of air which an animal is obliged to breathe, is consumed, suffocation ensues.

Oxygen is also the sole supporter of combustion; the same air which will not support life, will not support combustion, and *vice versâ;* as both combustion and respiration consume the same component part of the atmosphere

If oxygen constitute the vital part of the atmosphere, in which it exists only in the proportion of twenty-two parts in the hundred, it may be inquired whether the most beneficial effects would not follow, if this proportion could be increased? A little investigation will shew the error of this opinion. Pure oxygen is too great a stimulant; a sparrow confined in a jar of it, will live considerably longer than in the same quantity of atmospheric air, but even if continually supplied with pure oxygen, its life will be shortened. Dr. Higgins having caused a young man to breathe pure oxygen gas for a few minutes, his pulse,

which at first was at 64, soon increased to 120 beats in a minute. To such an acceleration of the powers of life, we should speedily fall victims; but under medical direction, pure oxygen, or a larger proportion of it than naturally exists in the atmosphere, has been administered for a short time with the happiest effects.

The accelerating effect of pure oxygen on animal life, may be inferred in a still more remarkable manner, from its astonishing effects in accelerating combustion; the exhibition of which affords some of the most brilliant experiments in the compass of chemistry. A wire not hot enough to kindle phosphorus in atmospheric air, will set fire to it, if it touch it in oxygen gas; and a piece of tinder, lighted only by a spark, will, in the same gas, set fire to steel, as if it were the most combustible material. Fill a receiver, open at the bottom, with oxygen gas, and place it over a dish containing mercury; introduce under the jar, a piece of phosphorus, which will immediately rise to the top of the mercury; take a hot wire, and without removing the jar out of the mercury, touch the phosphorus with it, by passing it through the mercury. The phosphorus will immediately burn with a flame of prodigious intensity. After the combustion, the interior surface of the glass will be covered with a white crust, which will be found to be phosphoric acid, and the mercury will have risen in the jar above its level at the outside. In this process the oxygen gas is decomposed; at a certain degree of heat, phosphorus has the property of attracting the base or solid particles of this gas, and the new compound is phosphoric acid, that is, a composition of the two simple bodies oxygen and phosphorus. The light and caloric which kept the oxygen in a gaseous state, together with part of the light and caloric of the phosphorus, is disengaged, in the form of what we call fire. When the experiment is conducted in such a manner that the products can be weighed, it is found that the phosphorus consumed, and oxygen absorbed, are exactly equal to the acid obtained. If the oxygen is pure, and the whole quantity is not consumed, the remaining portion will be unaltered, which is a proof that nothing has escaped from the phosphorus by which any change is produced.

All combustible bodies combine with oxygen, for their combustibility is nothing more than the power of forming such a combination. The product of the combination differs according to the nature of the material, and the quantity of oxygen with which it is combined.

To effect the combustion of sulphur in oxygen gas, take a jar, filled with the gas, and open at the bottom, from the shelf

of the pneumatic trough, by slipping it on to a dish containing water; it may then be conveyed to any convenient table. The jar should have a stopper at the top; from a cork which is known to fit it, should be suspended by a wire, at a distance equal to about three-fourths of the depth of the jar, a small plate of copper, in a horizontal position, and the wire should be affixed from the circumference, and not from the middle of the plate. A small piece of sulphur may be laid upon the plate, and kindled by means of a candle and blowpipe. The cork with its appendages may then be substituted for the stopper of the jar; during this operation, in the undisturbed atmosphere of a room, the oxygen will not escape, on account of its gravity. After its immersion, the sulphur immediately burns with a beautiful blue flame. When the fumes have disappeared, the water at the bottom of the jar will be found to have an acid taste; it will turn blue vegetable colours red, and effervesce with carbonated alkalies. It is therefore an acid, and as it is composed of sulphur and oxygen, it is called the *sulphuric acid*. It is found by experiments conducted for the purpose, that the water has gained a weight equal to the sulphur and oxygen consumed.

All acids are formed by the combination of oxygen with a different base; oxygen was therefore at one time considered the acidifying principle, but recent discoveries have shewn that it also contributes to the formation of alkalies.

The combustion of charcoal in oxygen gas may be effected in a similar manner to that of sulphur, the charcoal being set on fire by a small piece of tinder. The charcoal burns with vehemence, and throws out strong scintillations, with a brilliant light. When the combustion is over, the jar is still found to contain an elastic fluid, whose properties are very different from those of oxygen. It is found to be an acid, and as it is formed by the union of carbon and oxygen, it is called *carbonic acid gas*. Its properties will come under consideration in a subsequent section.

The well-known combustibility of the substances which have hitherto been directed to be consumed in oxygen gas, may render less striking the powers of this fluid than they would otherwise appear; this impression will be removed by attending to the combustion of iron or steel. A jar of oxygen, as in the former experiments, may be provided; a slender piece of iron or steel wire is coiled in the form of a bottle screw, and but little larger, by wrapping it round a rod of wood or metal. One end of the wire thus coiled should be fixed in a cork which will fit the jar containing the oxygen gas; the other end, which should hang down so as to enter the jar perpendicularly,

should have a small piece of tinder attached to it. The tinder must be lighted, and the wire quickly introduced into the oxygen, by substituting the cork to which the wire is attached for the stopper of the jar. The tinder is consumed in an instant, and the deflagration of the wire immediately follows. An intense light, with sparks, consisting of melted globules of the metal, are thrown out, and it forms, upon the whole, a more striking appearance than the combustion of any of the substances before mentioned. A watch-spring may be consumed in this way with great facility; it should be pointed at the part where it is connected with the tinder. In this experiment, the iron is actually reduced to a state of fusion, and this cannot be effected except at a temperature of above 20,000 degrees of Fahrenheit. The jar, therefore, unless open at the bottom, should contain water to the depth of two inches, to prevent the melted globules from breaking it. If the iron which has been thus burnt be collected, its weight will be found to exceed that which it had before the experiment, and this excess of weight is just equal to that of the gas consumed. In this state of its combination with oxygen, it is called *oxide of iron;* it has lost all its metallic properties, and approaches to the state of an earth.

All the metals combine with oxygen, and form oxides, but the facility with which they combine, is very different. With most metals the combination goes on at common temperatures, and without any perceptible disengagement of light or caloric. All that is in ordinary speech called tarnish or rust, is the combination of oxygen with the metal thus acted upon, and the rusts of the various metals are their oxides.

The action of a current of oxygen upon the metals may be agreeably shewn by using the metals in the state of filings. For this purpose, the oxygen should be inclosed in a bladder, to the neck of which a small tube is adapted. The filings should be laid upon an ignited piece of charcoal, and by pressing the bladder a current of oxygen will be driven upon them. The filings of iron, copper, zinc, and antimony, afford a more brilliant exhibition than other metals.

If a lighted candle be let down into oxygen gas, it will burn with a rapidity proportionate to the effects of oxygen in other cases of combustion: if it be drawn up, and the flame blown out, on letting it down again, it will be perfectly lighted from the spark of the snuff.

These examples sufficiently shew the power of oxygen in accelerating combustion; it may also be inferred from them, that whenever oxygen gas becomes concrete, caloric is disengaged, and is received by the nearest conductors. It is on this

principle that animal heat is accounted for: in respiration, there is a real consumption of oxygen, which is absorbed by the blood; to the blood, therefore, must be communicated a certain portion of heat, which is given out by the oxygen gas on its entering into a new combination. Hence the colder the season or the climate, and the denser the air, the more oxygen is inhaled, and the more heat is generated in the body. In breathing pure oxygen, an increase of heat in the lungs is very perceptible. In the formation of rust, and in other cases, in which the caloric cannot be detected, the slowness of the process accounts for the difference.

On reviewing the properties of oxygen, it must be evident, that if the atmosphere consisted either chiefly or entirely of it, the present system of nature in other respects could scarcely have existed; a spark would have set the world on fire, with a fervency producing its certain destruction. We shall next have occasion to treat of the fluid by which oxygen is diluted.

Of Nitrogen.

Atmospherical air, after its vital qualities have been exhausted by combustion or respiration, leaves a residuum, which is elastic and invisible like itself, but wholly incapable of supporting life or fire. Upon examination, it is found to consist, with some admixture, of a gas which is now called *nitrogen gas.* On the first framing of the new nomenclature, it was called azotic gas, from one of its powers of extinguishing life; but as it only had this property in common with all other gases devoid of oxygen, the present term has become generally adopted as preferable, being derived from its exclusive property of forming the base of nitric acid.

Nitrogen gas is most easily described by including many of its negative qualities; it has no taste; it neither reddens vegetable blue colours, nor precipitates lime-water; it is not absorbed by water. It unites to oxygen in several proportions; it also unites to hydrogen. Though incapable of being breathed alone, its base, nitrogen, is a component part of all animal substances. It is lighter than oxygen; Dr. Black found that a vessel of 1000 cubical inches, which will contain 315 troy grains of atmospheric air, will contain 335 of oxygen gas, but only 297 of nitrogen gas.

Nitrogen gas may be variously obtained; agreeably to the remark made above, if the oxygen be extracted from

atmospheric air, this substance will remain; and will generally be very pure, unless the oxygen has been extracted by respiration. If iron filings and sulphur, moistened with water, be put into a jar containing atmospherical air, this gas will, in a day or two, be all the air that remains in the jar, as the oxygen will be absorbed by the iron and sulphur. Phosphorus, or sulphuret of lime or potass, inclosed with common air in a jar, will produce a similar effect.

Nitrogen gas may likewise be obtained from animal substances. For this purpose, put some small pieces of lean muscular flesh into a retort, and cover them with weak nitric acid. The heat of a lamp will extricate the gas, which may be collected by the pneumatic apparatus.

It has been conjectured that nitrogen is not a simple substance, but no experiments have decisively proved this.

Atmospherical air contains 78 parts in the hundred by measure of nitrogen gas; the 22 remaining parts, or oxygen, being thus largely diluted, becomes proportionately less intense in its stimulating effects, and fit for the purposes of life, the length of which is increased by this source of moderation in its course. By mixing pure nitrogen gas and oxygen gas in the proportions just mentioned, a gas having all the properties of atmospheric air is the result.

Though animal life cannot be sustained for a moment by nitrogen gas; yet it is congenial to vegetables, and appears to be a part of their food; they derive it from its combination with oxygen in atmospheric air.

There are two other gaseous combinations of nitrogen with oxygen, besides that which forms atmospherical air:—nitrous oxide and nitrous gas; these we shall notice hereafter; although the proportions of their component parts differ but little, the difference in their properties is very great.

Of Hydrogen.

The third and last substance, which, in its simplest form, can only be obtained in an aërial state, is called *hydrogen*. This gas has long been generally known by the name of *inflammable air;* it is the gas which miners call the *fire damp*.

Hydrogen with oxygen forms water; and it is by the decomposition of water that chemists obtain it in the greatest abundance and purity. For this purpose, iron filings or turnings, or granulated zinc, are put into a retort, and covered with sulphuric acid diluted with four times its weight of water. A

violent effervescence ensues, a large quantity of gas is evolved, and issuing from the beak of the retort, is collected in the usual manner by the pneumatic apparatus. In this experiment, the acid is not decomposed; it is the oxygen of the water with which the acid is diluted, that seizes upon and oxidizes the metal, and the hydrogen in the same portion of water being then disengaged, passes over in the state of gas. The hydrogen obtained by using zinc is the purest; that obtained by using iron generally containing some carbon.

The process just described is the readiest for obtaining this gas, but it is evolved in every instance in which metals are tarnished or rusted by moisture, and it may be obtained in great quantities, by causing the vapour of water to pass through an iron tube, or through a tube of any kind, containing a coil of iron wire, heated to ignition. The operation is generally conducted by the use of a furnace, provided with small holes opposite each other, to admit the tube to pass through it.

Hydrogen, like oxygen and nitrogen, is invisible, elastic, and inodorous; but the last quality it seldom possesses, because it is very seldom perfectly dry, and when it contains water in solution, like alkaline sulphurets, its odour is considerably fetid. It generally contains half its weight of water, and when it is received over water, its volume is one-eighth larger than when received over mercury.

Hydrogen gas is the lightest of all substances, except light and caloric. When pure, it is nearly 13 times lighter than common air. It is this extreme levity which occasions its utility for inflating balloons. To shew its levity, lecturers frequently fill soap bubbles with it, and these ascend in the air with rapidity. A bladder, filled with the gas, has a tobacco-pipe fitted in its neck; the bowl of the pipe is dipped into a lather of soap, and being then taken out, the bladder is gently pressed, and a bubble being formed and detached in the usual manner, it instantly ascends.

Hydrogen gas is incapable of supporting life, but may be inhaled and exhaled a few times without any fatal effects; it is returned by the lungs unaltered, and does not therefore appear to be positively noxious, but only operates by excluding oxygen.

Although so currently called inflammable air, hydrogen gas is not capable of being burned, or of supporting combustion, unless oxygen be present; a lighted taper introduced into it, instantly goes out. If a bottle filled with hydrogen gas, be fired, by presenting a lighted body to its opened neck, this gas burns with a lambent flame, till entirely consumed. If the hydrogen be previously mixed with a quantity of atmospheric

air on presenting the taper, the combustion takes place at once with a loud explosion. Pilatre de Rozier, whose memorable death has been mentioned in the article on Aërostation, having mixed pure hydrogen gas with one-ninth of atmospheric air, began to respire the mixture; and when he attempted to set it on fire, an explosion which had almost depived him of life, instantly ensued: the sensation he experienced at the moment, appeared to him as if all his teeth were blown out; his temerity, however, at this time, occasioned him no permanent injury.

Considerable quantities of hydrogen are often liberated in mines, and catching fire after their mixture with atmospheric air, they occasion dreadful explosions. If oxygen is mixed with the hydrogen, instead of atmospheric air, the explosion is still more violent. When the combination is made for the purpose of experiment, two parts, by measure, of hydrogen, are mixed with one of oxygen, and the bottle in which the mixture is made should at least be entirely enveloped in a handkerchief, except at the neck, to confine the fragments, if it should be broken, as it generally is; if the bottle be entirely covered with strong cord tied round it, it may escape fracture. The explosion of the gases thus mixed, may be shewn very effectually by means of the bladder and pipe for filling soap-bubbles with hydrogen; for if the mixture be employed instead, the bubbles will explode on a lighted candle being presented to them as they ascend. If bubbles be formed on the surface of the lather in the bason, by increasing their number, and firing them, the loudness of the report may be increased at pleasure.

That water is in reality the union of oxygen and hydrogen, is proved not only by these gases being obtained by its decomposition, but by reversing the experiment, and producing water from the gases themselves. Fifteen parts, by weight, of hydrogen, being mixed with 85 parts of oxygen, and retained in a close vessel, if the hydrogen be fired by the electric spark, the gases will be converted into water, the weight of which will be equal to that of both the gases employed, and the gases disapppear. It is inferred, that in all cases of the combustion of hydrogen, water is produced; and as a proof of this, it is found that, in the experiment described above, for exploding the mixed gases, the bottle, though perfectly dry within before the explosion, is bedewed with moisture after it.

The oil and resin of vegetables are derived from the decomposition of water; and composts are partly beneficial as manures, from the hydrogen furnished in the process of putrefaction: if the compost be kept till this putrefaction is nearly over, its value is materially lessened, as the hydrogen flies off.

Hydrogen combines with a larger quantity of oxygen than any other body; its combustion, therefore, when mixed with oxygen, produces a more intense heat than any other combustion. This may be shewn with a bladder filled with oxygen and another with hydrogen, by causing a stream from each bladder to pass through a tube upon a piece of ignited charcoal, or any other burning combustible. Each of the bladders should be furnished with a stop-cock, and as there is some risk of a violent explosion, bladders may be used with more propriety than any other vessels.

Hydrogen is capable of combining with sulphur, phosphorus, carbon, and arsenic; and these compounds are respectively distinguished by the terms sulphuretted hydrogen, phosphuretted hydrogen, carburetted hydrogen, and arseniated hydrogen. The flame which it yields in combustion, is differently tinged according to the substance combined with it. Fire-works have been constructed, in which the diversity of colour in the flame was produced by an attention to this property.

Pit-coal, by distillation, affords carburetted hydrogen, which is employed in what are called the gas lights. The coal thus distilled is not lost, but is converted into coke, which is as valuable as the coal from which it was produced.

Sulphuretted hydrogen has an offensive smell, resembling rotten eggs; it is produced by dissolving the sulphurets in acids: that disengaged by the sulphuric acid burns with a blue flame; that produced by the nitric acid, burns with a yellowish white flame; the latter acid disengages the largest quantity of the gas.

Phosphuretted hydrogen, which has also a strong fetid, putrid smell, may be obtained by boiling in a retort a little phosphorus, with a solution of potass. If this gas comes in contact with the air, as it escapes from the retort, it takes fire, and a dense, conical wreath of smoke rises from it. It explodes if suddenly mixed with oxygen, oxy-muriatic acid, or nitrous oxide gas. The ignis fatuus, or jack-with-a-lantern, is attributed to the disengagement of this gas from the putrid effluvia common in the swampy places where that phenomenon is observed.

Arseniated hydrogen may be obtained by adding sulphuric acid, diluted with twice its weight of water, to four parts of granulated zinc and one of arsenic. Two parts of this gas, with one of oxygen, will explode loudly, and the products are water and arsenious acid.

Of Carbon.

Vegetables, when burnt or distilled in close vessels, till their volatile parts are entirely separated, leave a black, brittle, and cinerous residuum, which constitutes the greater part of the woody fibre, and is called *charcoal*. Charcoal contains a portion of earthy and saline matters, but when entirely freed from these and other impurities, a solid, simple combustible substance remains, which is called *carbon*.

Carbon exists naturally in a state of greater purity than it can be prepared by art; the diamond is pure carbon crystallized. The diamond, when pure, is colourless and transparent; it is the hardest substance known, and as it sustains a considerable degree of heat unchanged, it was formerly supposed to be incombustible. It may, however, be consumed by a burning-glass, and even by the heat of a furnace. The difficulty of burning it, appears to rise from its hardness; for Morveau and Tennant have rendered common charcoal so hard by exposing it for some time to a violent fire in close vessels, that it endured a red heat without catching fire. Common charcoal contains only 64 parts of diamond, or pure carbon, and 36 of oxygen in every 100.

The common charcoal of commerce is usually prepared from young wood, which is piled up near the place where it is cut, in conical heaps, covered with earth, and burnt with the least possible access of air. When the fire is supposed to have penetrated to the centre of the thickest pieces, it is extinguished by entirely closing the vents. When charcoal is wanted very pure, the product of this mode of preparing it will not suffice; for the manufactory of the best gunpowder, it is distilled in iron cylinders; chemists prepare it in small quantities, in a crucible covered with sand, and after they have thus prepared it, they pound it, and wash away the salts it contains by muriatic acid; the acid is removed by the plentiful use of water, and afterwards the charcoal is exposed to a low red heat. Pure charcoal is perfectly tasteless, and insoluble in water.

Charcoal newly prepared, absorbs moisture with avidity; it also absorbs oxygen and other gases, which are condensed in its pores, in quantity many times exceeding its own bulk, and are given out unaltered. Fresh charcoal, allowed to cool without exposure to air, and the gas then admitted, will absorb in the following proportion: one part of charcoal will absorb 2.25 times its bulk of atmospheric air immediately, and .75 more in four or five hours: of oxygen gas about 1.8 immedi-

ately, and slowly 1 more: of nitrogen gas 1.65 immediately: of nitric oxide 8.5 very slowly: of hydrogen gas about 1.9 immediately: carbonic acid gas 14.3 immediately. The greater part of these gases are expelled by a heat below 212°, and a portion even by immersing the charcoal in water. These absorptions are promoted by a low temperature; but at an elevated temperature, charcoal has such an affinity for oxygen, that it will abstract it from almost all its combinations. Hence its utility in reviving metals.

Fossil coal, and all kinds of bitumen, contain a large quantity of carbon: it is also contained in oils, resins, sugar, and animal substances.

Charcoal is one of the most unchangeable substances; if the access of air be prevented, the most intense heats have no other effect than that just mentioned of hardening it, and rendering its colour a deeper black. Insoluble in water, and incapable of putrefaction, it undergoes no change by mere exposure or age; and stakes, and other materials of wood which have been charred, or superficially converted into charcoal, have been preserved from decay for thousands of years; the ancients availed themselves of this mode of preparing stakes which were to be driven into the ground for foundations and other purposes.

The combination of carbon with various substances, are called carburets. Steel is a combination of iron and carbon, in which the proportion of carbon is very small—only about a two-hundredth part; it is to its carbon that it owes its valuable property of admitting to be tempered, of which we have fully treated in vol. I. Cast-iron contains more carbon than steel, but this difference is not the only cause of the difference of the properties of iron in the two states; from its carbon, however, cast-iron admits of being made hard or soft, nearly in the same manner as steel. Plumbago contains 90 parts of carbon, and but 10 of iron; it is from this excess of carbon, called a *hyper-carburet of iron*. The name of black-lead, by which it is most generally known, is evidently improper, as it contains not a particle of lead. On the contrary, the connexion of plumbago with iron might be inferred from its resemblance in some respects to that kind of cast-iron which contains most carbon; their fracture is much alike; and very fine filings of the iron tinge the hands nearly in the same manner as the powdered plumbago. Yet cast-iron seldom contains more than a forty-fifth part of its weight of carbon.

Charcoal possesses the singular property of combining with, and destroying, the odour, colour, and taste of various substances. Putrid and stinking water may be rendered sweet

by filtering it through charcoal-powder, or even by agitation with it. Common vinegar boiled with charcoal-powder, becomes perfectly limpid. Saline solutions that are tinged yellow or brown, are rendered colourless in the same way, so that they will afford white crystals. Malt spirit may be freed from its disagreeable flavour by distillation with about $\frac{1}{150}$ of its weight of charcoal. Tainted vessels, after having been well scoured, may have every remaining taint removed by rinsing them out with charcoal powder; and this powder will also restore the sweetness of flesh-meat but slightly tainted with putridity. As a dentrifice, charcoal, in the state of an impalpable powder, is unrivalled, at once whitening the sound teeth, and sweetening the breath by neutralizing the fetor that arises from those which are carious, or from a scorbutic state of the gums.

When charcoal is burnt in oxygen gas, nearly the whole of it disappears; it is converted by its combination with the oxygen into an aëriform fluid, which, having the properties of an acid, is called *carbonic acid gas*. It contains 28 parts by weight of charcoal, and 72 of oxygen in every 100. It was discovered by Dr. Black, in 1755, and the discovery constitutes a memorable epoch in the history of chemistry, as it was attended with so clear a demonstration of the fact, that gaseous substances could become concrete, or form a part of solid substances, and that, on the contrary, solid substances could assume the gaseous form.

Carbonic acid gas is nearly twice as heavy as atmospheric air, and it may therefore be poured from one vessel to another, or retained in a cask and drawn off like other liquors. Though invisible, yet if contained in a glass, the presence of something different from common air may be discovered by lighting a piece of paper, and putting it into the glass; the light will instantly go out, and the smoke becoming entangled in this heavy gas, will shew the quantity of the gas that may be present. The extinction of fire by this gas is instant and complete; and when by any accident it is breathed, it prevents the power of speech, and rapidly destroys life. As it is evolved in the process of fermentation, it is often present in vats, and the public journals frequently record instances of persons who have incautiously descended into these vessels to clean them, perishing from its baneful effects in a few moments.

Carbonic acid gas is always the result of the combustion of charcoal, which cannot be burnt in a close apartment, without imminent hazard of suffocation to the persons present. This gas is often contained in deep old wells, and places which have been long closed; wherever it is suspected to exist, it

will be proper to introduce a lighted candle, and if that burn as usual, no danger need be apprehended; but if it be extinguished, it may be taken for granted that the air is unfit to breathe. A quantity of water, particularly if mixed with quicklime, will, if thrown into a suspected place, absorb the carbonic acid which may be present. Carbonic acid gas constitutes what miners call the *choke damp*.

Carbonic acid, though so deleterious when breathed, often forms a palatable wholesome ingredient in food, as it possesses the strongly antiseptic properties of carbon, its base. Hence the acid taste of Pyrmont, Spa, and other mineral waters; hence the sparkling and agreeable briskness of fermented liquors, such as beer, cider, &c. Yeast, from the large quantity which it contains of it, has performed wonderful cures in putrid diseases. The atmosphere contains a very small portion of this gas, the use of which may be to neutralize the putrid miasmata continually flying about. Water may by pressure be caused to combine with nearly three times its own bulk of carbonic acid gas.

The combinations of carbonic acid with other substances, are called *carbonates*. Common chalk, lime-stone, and marbles, are all carbonates, and in their chemical composition differ but little from each other. Carbonic acid gas may be obtained from any of these, by putting them into a retort in powder, and pouring upon them a diluted acid, for example the sulphuric. The gas must be collected by the pneumatic apparatus. A cubical inch of marble contains as much carbonic acid, as, in the state of gas, would fill a vessel of six gallons.

Sulphur.

Sulphur, or brimstone, is a well-known substance, of a yellow colour, brittle, moderately hard, devoid of smell, but not entirely so of taste. Its specific gravity is 1.990. It is a non-conductor of electricity, and therefore becomes electric by friction.

Sulphur is extensively disseminated, and is obtained abundantly, both in a state of purity, and from its combinations with other substances. It flows from volcanoes, and is sublimed from the earth in some parts of Italy. It is combined more or less frequently with most ores, and is procured in large quantities from some of them, particularly those of iron and copper. In the Isle of Anglesea, it is sublimed from

the copper ore, and collected in large chambers, which are connected with the kilns by means of horizontal flues.

Sulphur unites with most of the metals, rendering them brittle, and increasing their fusibility. It is soluble in oils, and by heat in alcohol, but water has no immediate action upon it. Hydrogen gas dissolves it, and is then called sulphuretted hydrogen. This gas is evolved during the putrefaction of animal substances. Sulphur unites with phosphorus by heat; but with charcoal it does not combine.

If a bar of iron or steel, at a white heat, be rubbed with a roll of sulphur, the two bodies combine and drop down together in a fluid state, forming sulphuret of iron, a compound of the same kind as the native sulphuret of iron called pyrites, and which, from its abundance, supplies much sulphur.

If potass or soda be melted by a moderate heat, with equal parts of sulphur, in a covered crucible, it forms a substance, which, after cooling, is of a liver-brown colour. These compounds are respectively called the sulphuret of potass or soda.

Orpiment, or king's yellow, is a sulphuret; it is composed of arsenic and sulphur. Vermilion is the red sulphuret of mercury.

Sulphur sublimes at the heat of 170°, and is collected in the form of what are called *flowers of sulphur*. If heated to 185°, it becomes very fluid, but by a continuance of the heat its fluidity diminishes, and it even becomes thick; on being allowed to cool, its former fluidity returns before it becomes solid. If as soon as the sulphur has begun to congeal, the inner liquid part be poured out, the internal cavity will exhibit long needle-shaped crystals of an octahedral figure.

If sulphur be burnt in closed vessels, it is entirely dissipated in fumes or vapour. These fumes, which consist of sulphur and oxygen, are acidulous, and are called the *sulphuric acid*.

PHOSPHORUS.

Phosphorus is a yellowish, transparent substance, of the consistence of wax. It is luminous in the dark at common temperatures, and at 67° it emits a white smoke; it is rapidly consumed at 122°. It is preserved by keeping it in water; the water has, however, the effect of rendering it opaque, and even exposure to light alters it in some degree.

Phosphorus was originally prepared from urine, by a tedious and disagreeable process, but Gahn, a Swedish chemist, having

discovered that it existed in bones, it is now prepared from this class of bodies. The bones are calcined till they cease to smoke, after which they are reduced to a fine powder. This powder is put into a glass vessel, and sulphuric acid gradually poured upon it, till the farther addition of acid occasions no extrication of air-bubbles. This mixture is largely diluted with water, well agitated, and kept hot for some hours, it is then filtered, and afterwards evaporated slowly, till a quantity of white powder falls to the bottom. This powder by a second filtration is separated and thrown away. The evaporation is then resumed; and whenever any white powder appears, the filtration must be repeated in order to separate it. During the whole process, what remains on the filter must be washed with pure water, and this water added to the liquor. The evaporation is continued till all the moisture disappears, and nothing but a dry mass remains. This mass is put into a crucible, and kept melted in the fire, till it ceases to yield a sulphurous smell; it is then poured out. When cold, it resembles a brittle glass; it is pounded in a glass mortar, and mixed with one-third by weight of charcoal-dust. This mixture is put into an earthenware retort, to which is adapted a receiver, containing a little water. In a short time after the retort and its contents have become red-hot, the phosphorus slowly passes into the receiver drop by drop. It is generally formed into small cylinders, by moulding it under lukewarm water, in glass tubes; or by putting a cork into the extremity of the pipe of a glass funnel, into which hot water may then be poured, and the phosphorus being dropt in, will mould itself. From the remark made above, respecting the low temperature at which it burns, it is necessary to take great care that none of it adheres to the hand, especially under the nails, whence it would be with difficulty extracted, as the heat of the body would kindle it, and it burns with extreme ardour. If, however, it be thoroughly mixed with several times its bulk of hogs' lard, it may be held in the hand without injury

Phosphorus possesses a prodigious divisibility; a quarter of a grain having been administered in some pills to a person who was afterwards opened, all the internal parts were found to be luminous, and even the hands of the person who performed the operation, acquired the same appearance. Phosphorus has been administered by the French physicians in consumptive cases, in which it appears to have had a reviving effect on the patients, without raising the pulse in the same proportion; in cases of malignant fevers, and to stop the progress of gangrene, it has also succeeded beyond all hopes:

but except in small quantities, and in a state of extremely minute division, it is a certain poison; and should never be administered internally, except under the strictest medical inspection.

Phosphorus combines with oxygen, hydrogen, nitrogen, sulphur, most of the metals, and some of the earths. By combining with oxygen, that is, after combustion, it forms phosphoric acid. When the phosphoric acid is combined with any substance, that substance is called a *phosphate*. The phosphorus in bones is in the state of phospate of lime. The combination of phosphorus with iron forms that kind of iron called *cold-short*, which is brittle when cold, though malleable when heated.

Phosphorus rubbed in a mortar with iron filings, takes fire instantly. Phosphoric match-bottles are prepared by mixing one part of flour of sulphur with eight of phosphorus. If a very small quantity of this mixture be taken out on the point of a match, and rubbed upon a cork or any similar body, the match becomes lighted.

Phosphorus, surrounded by cotton rubbed in powdered rosin, and placed under the receiver of an air-pump, takes fire after the exhaustion, and exhibits a beautiful appearance when the air is gradually re-admitted.

Of Metals.

The metals, from their extensive and diversified utility, are amongst the most interesting classes of substances existing. They are supposed to be simple bodies, and not a single fact has ever been ascertained which shews that they can be converted into each other; yet to accomplish this, the alchemists exhausted their estates and their lives.

The metals are distinguished by their possessing all or the greater part of the following properties; hardness, tenacity, lustre, opacity, fusibility, malleability, and ductility; and they are excellent conductors of caloric, electricity, and galvanism.

Metals are generally found in mountainous countries; they are sometimes met with in a state of purity, and are then said to be found native: but they are mostly combined with other bodies, and when combined with other bodies in such quantity as to be worth separating, the substance is called an ore of the metal it contains.

All the metals are susceptible of crystallization; the easiest mode of obtaining their crystalline form, is to let out the middle part just after they have begun to congeal: the interior of the crust thus left, assumes a crystalline form.

The metals are fusible at very different temperatures; mercury, for example, does not become solid, unless cooled down to—39°, and platina is not softened by the heat at which cast-iron runs like water.

Metals differ from each other as much in hardness as in fusibility. Kirwan has adopted a very simple mode of shewing their comparative hardness by figures; we shall adopt his plan, which he thus explains:

3. Denotes the hardness of chalk.
4. A superior hardness, but yet what yields to the nail.
5. What will not yield to the nail, but easily, and without grittiness to the knife.
6. That which yields more difficultly to the knife.
7. That which scarcely yields to the knife.
8. That which cannot be scraped by a knife, but does not give fire with steel.
9. That which gives a few feeble sparks with steel.
10. That which gives plentiful, lively sparks.

Great specific gravity was formerly considered as one of the chief characteristics of the metals, the lightest metal being about twice as heavy as the heaviest body of any other sort; but the discovery of several bodies, which possess all the characters of the metals, excepting weight, and which cannot therefore be omitted in the list of metals, has caused great specific gravity to be no longer distinctive.

If a metal be exposed to a heat which will keep it in fusion, it may, without suffering any alteration but that of its figure, (which will adapt itself to the vessel,) be kept any length of time in that state, provided the access of air to its surface be entirely prevented. But if the fusion be conducted in open vessels, the surface of the metal loses its metallic brilliancy, and if its apparent scum be removed, another is soon formed, until the whole of the metal disappears, and instead of it we have an earthy opaque powder which soils the hands. Upon collecting and weighing this powder, it is found to be heavier than the metal from which it was produced. This process was by the ancient chemists called *calcination*, and the product of it we called a *calx*; they knew not the cause of it, and were therefore wholly unable to account for the increase of weight which they obtained by it; but the moderns having thoroughly investigated the subject, consider all metals as combustible bodies; that in the operation just described the metal has suffered combustion, and that therefore the oxygen of the atmosphere has combined with it, as it combines with all other

bodies during combustion, and that it is solely from the oxygen absorbed that its additional weight is derived. In proof of this, they find by suitable experiments, that the oxygen absorbed is exactly equal to the weight acquired; and also, that when the oxygen is taken away, by presenting some substance for which it has a greater affinity, the metal acquires all its original properties, and becomes of the same weight as at first. Hence for the vague term calx, the modern chemists used the word *oxide*, to denote the earth-like combination of a metal with oxygen; and the act or process in which this change takes place, is called *oxidation*.

Oxygen will not combine with metals in all proportions, as acids will do with water, but only in one or two, or at most a few proportions. When the proportion of oxygen varies, the oxide of the same metal assumes different colours; the colour is therefore selected to distinguish these differences: hence we have the *yellow oxide of lead*, the *red oxide of lead*, &c. When the oxygen which converts a metal into an oxide, is supplied by an acid, the name of the solvent, as well as the colour of the oxide, is sometimes given, thus we have the *white oxide of lead by the acetous acid*.

Some of the metals are so much disposed to oxidation, that they become oxides at all temperatures; iron is a metal of this description; the rust to which it changes in air or water is its red oxide.

If the oxide of a metal be exposed to a strong heat, it vitrifies, or is converted into a substance resembling common glass; the substances employed for enamel painting, for colouring glass, and for glazing earthenware, are mostly prepared from metallic oxides.

If any of the malleable metals be hammered, its combined caloric becoming sensible, renders it hot, and passes off to surrounding bodies; the metal at the same time is rendered denser, harder, more rigid, and in general more elastic. A portion of the caloric, to which, in common with other bodies, metals owe their softness, appears to be driven out of it; for its former state returns by heating it to ignition. Rolling produces the same effect as hammering.

The metals combine with each other, and besides oxygen, with the simple substances, sulphur, carbon, and phosphorus. When two metals are combined together, the mixture is called an *alloy* of that metal whose weight predominates.

Previous to the year 1730, only eleven metals were known, the list is now increased to thirty, chiefly by recent discoveries, and the probability is very strong, that there exists a much greater number. The metals may be divided into two general

classes;—the malleable and the brittle; the brittle metals may be further subdivided into those which are easily fused, and those which are fused with difficulty. We shall enumerate them, in each of these classes, in the order of their specific gravity.

I. *Malleable Metals.*

1. Platina,	8. Copper,
2. Gold,	9. Iron,
3. Mercury,	10. Tin,
4. Lead,	11. Zinc,
5. Palladium,	12. Sodium,
6. Silver,	13. Potasium.
7. Nickel,	

II. *Brittle Metals, fused without difficulty.*

1. Bismuth,	3. Antimony,
2. Arsenic,	4. Tellurium.

Brittle Metals, of difficult Fusion.

1. Tungsten,	8. Titanium,
2. Uranium,	9. Chromium,
3. Rhodium,	10. Columbium,
4. Cobalt,	11. Cerium,
5. Molybdenum,	12. Osmium,
6. Manganese,	13. Iridium.
7. Tantalium,	

Platina.

The specific gravity of platina, after hammering, is 23.000. It therefore holds the pre-eminence of all bodies in point of weight, and it has other extraordinary properties.

It is incapable of tarnishing by exposure to the air. The strongest mineral acids have no effect upon it, if employed separately, nor will the strongest fire melt it, unless urged by oxygen gas; a crucible of it not thicker than a sheet of paper, will endure the heat of the best furnace, and come out unaltered. When intensely heated, it possesses, like iron, the property of welding, but the labour of working it is very great. Its hardness is 7.5. Its colour is between that of iron and silver.

Platina was unknown in Europe before the year 1741, when a quantity of it was brought by Charles Wood, from Jamaica. It was supposed to be found only in the gold mines in Peru, but Vanquelin has met with it in Spain, in the mines of Gua-

dal-canal. Its name, in the language of Peru, signifies *little silver*, and on its great specific gravity being ascertained, attempts were made to prevent its use, lest gold should be adulterated with it. It has never been met with except in the metallic state, in the form of smooth grains of all sizes up to that of a pea, but very seldom larger.

Platina may be fused by a powerful burning glass; but its total infusibility by ordinary means, has caused various processes to be resorted to, for obtaining it in a solid, malleable state. For this purpose it must be dissolved in an acid; oxy-muriatic acid and nitro-muriatic acid both dissolve it. The latter acid should consist of one part of nitric, and three of muriatic acid. The solution is very corrosive, and tinges animal substances of a blackish brown colour; it affords crystals by evaporation. Count Moussin Pouschin directs malleable platina to be prepared from its solution as follows: Precipitate the platina by adding a solution of muriate of ammonia, and wash the precipitate with a little cold water. It is red-coloured, which distinguishes this metal from gold. Reduce it in a convenient crucible to the well-known spongy metallic texture, wash the mass obtained two or three times with boiling water, to carry off any portion of saline matter that may have escaped the action of the fire. Boil it in a glass vessel for about half an hour, in as much water mixed with one-tenth part of muriatic acid, as will cover it to the depth of about half an inch. This will carry off the iron that might still exist in the metal. Decant the acid water, and edulcorate or strongly ignite the platina. To one part of this metal take two parts of mercury, and amalgamate in a glass or porphyry mortar. This amalgamation takes place very readily. The proper method of conducting it, is to take about two drachms of mercury to three drachms of platina, and amalgamate them together, and to this amalgam may be added alternate small quantities of platina and mercury, till the whole of the two metals is combined. Several pounds may be thus amalgamated in a few hours, and in the large way a proper mill might shorten the operation. As soon as the amalgam of mercury is made, compress it in tubes of wood, by the pressure of an iron screw upon a cylinder of wood adapted to the bore of the tube. This forces the superabundant mercury from the amalgam, and renders it solid. After two or three hours, burn upon the coals, or in a crucible lined with charcoal, the sheath, in which the amalgam is contained, and urge the fire to a white heat; after which the platina may be taken out in a very solid state, fit to be forged.

The ductility of platina is such, that it has been drawn into wire of less than the two-thousandth part of an inch in diameter. This wire admits of being flattened, and is stronger than that of gold or silver, of the same thickness.

Platina will not combine with gold except in a violent heat. When not more than $\frac{1}{47}$th of the alloy is platina, the gold is not perceptibly changed in colour; but if the proportion be materially greater, the paleness of the gold betrays its impurity. Added in the proportion of one-twelfth to gold, it forms a yellowish-white metal, highly ductile, and so elastic, that Hatchett supposed it might be used for watch-springs and other purposes. Its specific gravity was 19.013.

It also requires a violent heat to make platina and silver combine; the silver becomes less white and ductile, but harder. If the two metals be kept for some time in fusion, they separate, and the platina, from its greater weight, sinks to the bottom.

The alloy of copper and platina is hard, yet ductile, while the copper is in the proportion of three or four parts to one. This alloy is not liable to tarnish, especially when the platina predominates, and it is therefore excellent for the specula of reflecting telescopes, as platina takes an excellent polish, and reflects a single image; the addition of a little arsenic improves this alloy. But copper is much improved, in colour, grain, and susceptibility of polish, when the platina is only in the proportion of a tenth or a fifteenth.

Alloys of platina with tin or lead, are very apt to tarnish: that with lead is formed at the strongest heat; it is not ductile, and the lead is not absorbed by the cupel, unless it is in excess, and even then the separation of the lead is not complete.

Platina unites easily with tin; the alloy is very fusible, but its grain is coarse and brittle; it is ductile, when the proportion of tin is large; it becomes yellow by exposure to the air.

Zinc renders platina more fusible, and forms with it a very hard alloy; the zinc cannot be entirely separated by heat.

Bismuth and antimony likewise facilitate the fusion of platina, with which they form brittle alloys, and are not wholly separated by heat. Arsenic has the same effect as these metals in promoting its fusion.

Platina has not been united to forged iron, but with cast iron it forms an alloy which resists the file.

If phosphorus be thrown upon red-hot platina, the metal is fused, and forms a phosphuret, which is of a silvery white, very brittle, and hard enough to strike fire with steel. As heat expels the phosphorus, Pelletier proposed this as an easy method of purifying platina; but he afterwards found that

the last portions of phosphorus were retained by too strong an affinity.

Several of the metallic salts decompose the solution of muriate of platina. Muriate of tin is so délicate a test of it, that a single drop, recently prepared, gives a bright red colour to muriate of platina, which before this addition is so clear as to be scarcely distinguished from water.

If the nitro-muriatic solution of platina be precipitated by lime, and the precipitate digested in sulphuric acid, a sulphate of platina will be formed. A subnitrate may be formed in the same way.

Platina does not form a direct combination with sulphur, but is soluble by the alkaline sulphurets, and precipitated from its nitro-muriatic solution by sulphuretted hydrogen.

The fixedness of platina admirably fits it for crucibles, and many other chemical utensils, which may be made thinner of this than of any other material whatever. It is, however, besides the disadvantage of its expense, liable to corrosion from caustic alkalies, and some of the neutral salts.

If ether be mixed and agitated with the nitro-muriatic solution of platina, it takes up the metal, and as it will soon float on the surface of the solution, it may be poured off, and if brushed over the clean surface of any other metal, it will soon evaporate, and impart to them a coating of platina.

Gold.

Gold is the most malleable, ductile, and brilliant of all metallic substances, and, next to platina, the heaviest and most indestructible.

Gold is seldom found except in the metallic state. It has been obtained in every quarter, and almost every country of the globe, but South America supplies a greater quantity of it than all the rest of the world.

Many laborious experiments have been separately made, by able chemists, who appear to have established the fact, that gold exists in vegetables.

A single grain of gold can be made to cover an area of more than 400 square inches; a wire one-tenth of an inch in diameter, will support a weight of 500 pounds, and Dr. Black has calculated that it would take fourteen millions of films of gold, such as cover some fine gilt wire, to make up the thickness of one inch, whereas the same number of leaves of common writing paper would make up nearly three-quarters of a mile

Though cpacity is enumerated as one of the characters of the metals, yet gold, when the $\frac{1}{282000}$th of an inch thick, which is about the thickness of ordinary gold leaf, transmits light of a lively bluish green colour. Perhaps all the other metals, if they could be equally extended, would shew some degree of transparency, but none of them can be made so thin.

The specific gravity of gold, unhammered, is 19.258, and is increased but little by hammering. Its hardness is 6. It melts at 32°, of Wedgwood; and if pure, its colour when in fusion is not yellow, but a beautiful bluish green, like the light which it transmits.

Gold cannot be volatilized except at an extreme heat. The utmost power of Parker's celebrated burning lens, exerted upon it for some hours, did not cause it to lose any weight which could be ascertained; but Lavoisier found that a piece of silver, held over gold melted by a fire maintained with oxygen gas, was sensibly gilt; and perhaps the same delicate test would have shewn its volatility by the lens.

After fusion, gold will assume the crystalline form. Tillet and Mongez obtained it in short quadrangular pyramidal crystals.

Gold unites with most of the metals. Silver renders it pale; when the proportion of silver is about one-fifth part, the alloy has a greenish hue. Silver separates from gold as from platina, if the alloy be kept for some time in fusion.

Gold is strongly disposed to unite with mercury; this alloy forms an amalgam, the softness of which is in proportion to the quantity of mercury. It is by mercury, that in South America, gold is chiefly obtained from the earth with which it is mixed, and the gold is separated from the mercury by distillation. This alloy readily crystallizes after fusion. It is applied by gilders to the surface of clean copper, and the mercury is driven off by heat.

Gold unites freely with tin and lead, but both these metals considerably impair its ductility. Of lead, one-quarter of a grain to the ounce renders the gold brittle; but tin has not so remarkable an effect.

Copper increases the fusibility of gold, as well as its hardness, and deepens its colour. It forms the usual addition to gold for the purpose of coin, plate, &c. The standard gold of Great Britain is twenty-two parts pure gold, and two parts of copper; it is therefore called "gold of twenty-two carats fine."

Iron forms an alloy with gold, so hard as to be fit for edge tools. Its colour is gray, and it obeys the magnet.

Arsenic, bismuth, nickel, manganese, zinc, and antimony, render gold white and brittle. When the alloy is with zinc in equal proportions, it has a fine grain, takes a high polish, and from these qualities, and its being not liable to tarnish, it forms a composition not unsuitable for the mirrors of telescopes.

For the purpose of coin, Hatchett considers an alloy consisting of equal parts of silver and copper as the best, and copper alone as preferable to silver. The same distinguished chemist gives the following order of different metals, arranged as they diminish the ductility of gold: viz. bismuth, lead, antimony, arsenic, zinc, cobalt, manganese, nickel, tin, iron, platina, copper, silver. The first three were nearly equal in effect, but the platina was not quite pure.

The nitric acid will take up a very minute quantity of gold, but the nitro-muriatic and oxy-muriatic acids are its only real solvents. The two latter acids are of a similar nature, and their effects on gold are increased by concentrating them, by enlarging the surface of the gold, and by the application of heat. The solution is of a yellow colour, caustic, and tinges the skin of a deep purple. By evaporation it affords yellow crystals, which take the form of truncated octahedrons. These crystals are a muriate of gold; they may be dissolved in water, and will stain the skin in the same manner as the acid.

Most metallic substances precipitate gold from its solution in the nitro-muriatic acid: lead, iron, and silver, precipitate it of a deep and dull purple colour; copper and iron throw it down in its metallic state; bismuth, zinc, and mercury, likewise precipitate it. When precipitated by tin, it forms the *purple precipitate of Cassius*, which is much used by enamellers and manufacturers of porcelain.

Ether, naphtha, and essential oils, take gold from its solvent, and from liquors which have been called potable gold, and are used in gilding; we shall describe the process in the account of gilding, among the miscellanies at the conclusion of the present volume. The gold obtained from these fluids by evaporation, is extremely pure.

If diluted nitro-muriatic solution of gold be employed to write with upon any substance, and the letters, while yet moist, be afterwards exposed to a stream of hydrogen gas, the gold will be revived, and the substance will appear gilt. Ribbons may be gilt in this manner. Sulphurous acid gas revives the gold in the same manner.

Lime and magnesia precipitate gold from its solution in the form of a yellowish powder. Alkalies do the same, but an excess of alkali redissolves the precipitate. The precipitate

obtained by means of a fixed alkali appears to be a true oxide; it is taken up by the sulphuric, nitric, and muriatic acids, but separates by standing with crystallizing. The precipitate by gallic acid is of a reddish colour, and very soluble in the nitric acid, to which it communicates a blue colour.

Gold precipitated from its yellow solution by ammoniac, forms a powder called *fulminating gold;* this dangerous compound detonates by friction, or a very gentle heat. It cannot be prepared or preserved without great risk. Macquer gives an instance of a person who lost both his eyes by the bursting of a bottle containing some of it, and which exploded by the friction of the glass stopper against an unobserved grain of it in the neck of the bottle.

Green sulphate of iron precipitates gold of a brown colour, but this soon changes to the colour of gold.

The alkaline sulphurets precipitate gold from its solution; the alkali unites with the acid, and the gold falls down combined with sulphur; the sulphur may be expelled by heat.

The alkaline sulphurets will also dissolve gold; thus if equal parts of sulphur and potass, with one-eighth of their joint weight of gold in leaves, be fused together, the mixture, when poured out and pulverized, will dissolve in hot water, to which it gives a yellowish green hue. Stahl wrote a dissertation to prove that Moses dissolved the golden calf in this manner.

Sulphur alone has no effect upon gold. The process called dry-parting is founded upon this circumstance. This is used for separating a small quantity of gold from a large quantity of silver. The alloy is fused, and flowers of sulphur are thrown upon its surface: the sulphur reduces the greater part of the silver to a black scoria. The small remainder of the silver may now be separated by solution in nitric acid. The advantage of the operation consists in saving the large quantity of nitric acid which would have been required to dissolve the silver of the alloy in its original state.

The heat produced by the electro-galvanic discharge, reduces gold to the state of a purple oxide.

Mercury.

Mercury is distinguished from all other metals by its fluidity, at the common temperature of the atmosphere. Its colour is white, and its surface is like that of polished silver. Its specific gravity is 13.580, and it is therefore the heaviest of all substances, excepting platina and gold.

Mercury boils at 655°; and does not cease to be a fluid,

unless at or below the temperature of —39°; in Russia and Hudson's Bay, this temperature sometimes occurs naturally, and in Britain it has been obtained by a freezing mixture; mercury has then been examined, and found to be perfectly malleable, working like soft tin. Experiments with artificial cold afford but few opportunities for exhibiting this property, but at Hudson's Bay, where surrounding objects were all equally cold, frozen mercury has been beaten upon an anvil into sheets as thin as paper. A mass of it being thrown into a glass of warm water, became fluid, but the water was immediately frozen, and the glass shivered to pieces. To the touch, frozen mercury excites the same sensation as red-hot iron.

Mercury is frequently obtained from the mines in the pure metallic state; sometimes it is combined with silver, but mostly with sulphur, in combination with which it is called *cinnabar*, when the mixture is of a red colour, but ethiop's mineral, when it is black. These are both sulphurets of mercury. Mercury is supplied by many countries. The mines of Idria, in the circle of lower Austria, have been wrought for 300 years, and are estimated to yield 100 tons annually. From Spain, which supplies large quantities, it is exported to South America, for amalgamating with gold, for which use the consumption is so prodigious, that the mine of Guança Velica, in Peru, does not supply enough. This mine is a vast cavern, 170 fathoms in circumference, and 480 fathoms deep.

Cinnabar, to obtain the metal from it, is mixed with quick-lime, and then submitted to heat. The lime combines with the sulphur, and the mercury, which sublimes from the mixture, is collected in receivers. Mercury sublimes at the heat of 600°, and then has the appearance of a whitish smoke. In this state of vapour, its elasticity renders it capable of bursting the strongest vessels, if the attempt be made to resist its expansion. Distillation is the ordinary means of purifying mercury.

Mercury combines very freely with gold, silver, lead, tin, bismuth, and zinc; not so freely with copper, arsenic, and antimony; for iron its affinity is extremely slight, and less so still, if possible, for platina.

The alloy of mercury with any metal, if the mercury predominates so far as to render it soft, and of the consistence of butter, is called an *amalgam*. These amalgams are much employed in silvering and gilding, as the mercury is easily driven off by heat, and the fixed metal is left behind. The metal with which the backs of looking-glasses are coated, is an amalgam of tin and mercury.

The number of metals with which mercury combines, renders it extremely liable to adulteration. The union is in

some cases so strong, that the baser metal will rise along with it in distillation. The experienced eye can, however, determine very small adulterations, by the want of perfect fluidity and brightness. Impure mercury also soils white paper, and the presence of lead may be detected by agitating the metal with water, by which means it will be oxidized. Or a very minute quantity of lead, present in a large quantity of mercury, may be detected by solution in nitric acid, and the addition of sulphuretted water. A dark brown precipitate will ensue, and will subside in the course of a few days. One part of lead may thus be separated from 15263 parts of mercury. Bismuth is detected by pouring a nitric solution, prepared without heat, into distilled water; this metal will be separated in the form of a white precipitate. If tin be present, a weak solution of muriate of gold will cause a purple precipitate.

By agitating mercury for some time in oxygen or atmospheric air, a part of it is converted into a black oxide.

Most of the acids have more or less action on mercury. The sulphuric acid requires the assistance of heat, and sulphurous acid gas is disengaged during its action, and a white oxide is formed, which becomes yellow by pouring hot water upon it, and is then called *turbith mineral;* it is a sub-sulphate of mercury; the water holds in solution sulphate of mercury.

The nitric acid dissolves mercury rapidly without heat; nitrous gas is disengaged, and the colour of the acid at the same time becomes green. If the acid be strong, it will take up its own weight of mercury in the cold, and will bear dilution; heat will enable the acid to dissolve much more of the metal, and the addition of distilled water will form a precipitate, which is yellow if the water be hot, and white if it be cold. This, from its resemblance to the turbith mineral mentioned above, is called *nitrous turbith.*

All the combinations of mercury with nitric acid are strongly caustic, and form a deep black or purple spot on the skin. When nitrate of mercury is exposed to a gradual and long continued low heat, it gives out a portion of nitric acid, and is converted into a bright red oxide; this oxide retains a small portion of nitric acid; it is called *red precipitate,* which is employed in medicine as a caustic. This red oxide parts with its oxygen simply by heat, and the mercury recovers its metallic state. The finest precipitate is made, by distilling the mercurial solution till no more vapours arise; then adding several successive portions of acid, and distilling it dry after each addition. The precipitate will thus be obtained in small crystals of a superb red colour. Red precipitate may be

prepared by heat only: the mercury must for this purpose be kept at the heat of about 600° for several months; the red oxide thus formed was called *precipitate per se*.

The acids, the alkalies, the earths, and most of the metals, precipitate mercury from its solution in the nitric acid. The precipitates by alkalies have the property of exploding, if triturated with one-sixth of their weight of flowers of sulphur, and afterwards gradually heated.

The following is Howard's method of preparing fulminating mercury: dissolve one hundred grains of mercury by heat in an ounce and a half by measure of nitric acid. Pour this solution, when cold, upon two ounces by measure of alcohol in a glass vessel, and apply heat till an effervescence is excited. A white vapour undulates on the surface, and a powder is gradually precipitated, which is to be immediately collected on a filter, well washed, and cautiously dried, at a low temperature. Slight friction, or a very gentle heat, causes this powder to detonate. Brugnatelli made fulminating mercury by pouring an ounce of alcohol on two drachms of the yellow oxide of this metal, and adding at twice ten drachms of strong fuming nitrous acid. The alcohol is converted into ether, which escapes in very copious vapours. All the oxides of mercury may be rendered fulminating by this process.

The muriatic acid does not act on mercury, except by long digestion, which enables it to oxidize a part, and it dissolves the oxide. This acid, however, completely dissolves the mercurial oxides, which, when nearly in the metallic state, or containing but little oxygen, form the muriate of mercury. When the oxy-muriatic acid is employed, the *oxy-muriate* of mercury, or *corrosive sublimate*, is formed. Corrosive sublimate is highly caustic and poisonous.

The mild muriate of mercury, or calomel, is prepared by triturating the oxy-muriate with three-fourths of its weight of metallic mercury, and then subliming the mixture three or four times in succession. If calomel be not perfectly insipid, and insoluble by long boiling in water, it may be suspected to contain corrosive sublimate, and consequently to be poisonous.

The difference between corrosive sublimate and calomel consists only in the different proportions of the same component parts, and to point these out will shew, in a striking manner, how small a difference in the proportion of the same component parts, may create an essential difference in the compound. In 100 parts, according to the analysis of Chenevix, the

	Mercury.	Oxygen.	Muriatic acid.
Corrosive muriate contains......	69.7	12.3	18
Mild muriate......................	79	9.5	11.5

Sulphur readily combines with mercury. If triturated with this metal in a mortar, it forms with it a black sulphuret, formerly called *ethiop's mineral*. This compound may also be formed by adding to sulphur in fusion one-fourth of its weight of mercury.

If ethiop's mineral, or black sulphuret of mercury, be sublimed, it affords the red sulphuretted oxide, or artificial cinnabar. This artificial cinnabar, when pounded and washed for painters' use, is called *vermilion*. To prepare it with accuracy, let 300 grains of mercury and 68 of sulphur, with a few drops of solution of potass to moisten them, be triturated in a porcelain mortar, with a glass pestle, till converted to the state of black oxide. Add to this 160 grains of potass, dissolved in as much water. Heat the vessel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, so that the oxide may be constantly covered to the depth of near an inch. The trituration must be continued about two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which usually happens when a large part of the fluid is evaporated. It then passes very rapidly to a red. No more water is to be added, but the trituration is to be continued without interruption. When the mass has acquired the consistence of jelly, the red colour increases in brightness with surprising rapidity. The instant the colour has acquired its utmost beauty, the heat must be withdrawn, otherwise the red passes to a dirty brown. This is Kirchoff's method of preparing vermilion. Count Moussin Pouschin discovered that the brown colour may be prevented by taking the sulphuret from the fire as soon as it begins to be red, and placing it in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. By this treatment an excellent red is obtained.

Phosphorus, mixed with red oxide of mercury, and distilled, forms a *phosphuret of mercury*, which is of a black colour, and in the air exhales phosphoric vapours.

Palladium.

Palladium is of a grayish white colour, scarcely distinguishable from platina, and takes a good polish. It is ductile, and very malleable; flexible, when reduced to thin slips, but not very elastic. Its fracture is fibrous, and in diverging striæ, shewing a kind of crystalline arrangement. It is harder than wrought iron. Its specific gravity is about 10.9, but may be increased by hammering and rolling to 11.8. It is a less perfect

conductor of caloric than the other metals, and less expansible, though in this respect it exceeds platina.

Palladium was discovered by Dr. Wollaston in native platina. When exposed to a strong heat, its surface tarnishes a little, and becomes blue, but by increasing the heat, it becomes bright. By an intense heat, it is fused, but not oxydized. Its oxides, formed by means of acids, may be reduced by heat alone.

Palladium may be obtained by adding to a nitro-muriatic solution of crude platina, a solution of prussiate of mercury, on which a flaky precipitate will gradually be formed of a yellowish white colour. This is prussiate of palladium, from which the acid may be expelled by heat.

The sulphuric, the nitric, and muriatic acids, dissolve a small portion of palladium, and acquire by it a red colour. The nitro-muriatic acid dissolves it rapidly, and acquires a deep red.

Alkalies and earths precipitate palladium from its solutions, generally of a fine orange colour; an excess of alkali partly redissolves the precipitate.

Alkalies act upon metallic palladium, and this action is assisted by the contact of air.

Green sulphate of iron precipitates palladium in a metallic state, and all the metals, except gold, silver, and platina, do the same. Prussiate of mercury produces a yellowish white precipitate, and as it does not precipitate platina, it is an excellent test of palladium.

Palladium forms with gold a gray alloy, harder than gold, less ductile than platina, and of a coarse-grained fracture.

With an equal weight of platina, it resembles platina in colour and hardness, but it is not so malleable, and melts at a heat a little higher than is requisite to fuse the palladium. The specific gravity of this alloy is 15.141.

With an equal weight of silver, the alloy is harder than silver, but softer than wrought iron, and its polished surface resembles platina, except that it is rather whiter; specific gravity 1.29.

Equal parts of palladium and copper, are a little more yellow, break more easily, assume somewhat of a leaden hue when filed, and are harder than wrought iron. Specific gravity 10.392.

Lead increases the fusibility of palladium, and forms with it an alloy of a gray colour, fine-grained fracture, harder than any of the preceding alloys, but very brittle.

With tin, bismuth, iron, and arsenic, palladium forms brittle alloys: that with bismuth is very hard.

Lead.

The colour of lead is a bluish white; its specific gravity is 11.352; its hardness 5; it is the softest, the least elastic and sonorous, of all metals used in the arts. It melts before ignition. It has scarcely any taste, but friction causes it to emit a peculiar smell. It stains paper and the fingers of a bluish black.

Lead is very malleable, and therefore easily reduced to thin plates by the hammer; but hammering neither increases its specific gravity or hardness. Its ductility is not great; a wire one-tenth of an inch in diameter, will support only 29¼ pounds.

It is not certainly known that lead has ever been found in the metallic state; the only lead ore that is extensively found and worked, is a sulphuret of lead; it is called *galena*, and is generally found in veins, both in siliceous and calcareous rocks. Lead ore frequently contains silver, and often antimony and bismuth.

To obtain lead from galena, the galena is pulverized, and separated by washing from earthy admixtures; it is then roasted in a reverberatory furnace, and afterwards melted in contact with charcoal. When the lead contains a quantity of silver worth extracting, it is fused in a strong fire, and the wind from a pair of bellows being directed over its surface, the whole of it is in succession converted into a yellow scaly substance called litharge, which being driven off as it forms, the silver is left at the bottom of the crucible. The litharge is a sub-carbonate of lead, and by fusing it with charcoal the lead is revived.

Of the uses of lead in its metallic state, we have already treated in vol. I. When lead is fused in an open vessel, its surface quickly loses its lustre, and a scum appears, which is soon converted into a darkish gray powder. In the heat usually employed to melt lead, this gray powder or oxide sustains no further alteration; but if spread out upon a suitable surface, and exposed to a low red heat, it becomes successively whitish, yellow, and lastly of a bright orange red. The yellow oxide is called by painters *masticot;* the red they call *minium*, or merely *red lead*. If the heat be urged much further, red lead is converted into litharge, which is a semi-vitreous substance, that by a little further heat becomes a complete yellow glass, of so fusible a nature, as to penetrate and destroy the best crucibles. This glass enters into the composition of flint-glass. It promotes its fusibility, renders it heavier than other glass, better capable of bearing sudden changes of temperature, and from its greater softness, more suitable for cutting and polishing.

When lead is exposed to the atmosphere, the brightness of its surface gradually diminishes, till it is nearly of the same colour as the gray oxide produced by heat; this oxide forms an even but very superficial covering, and it defends the metal from any further change.

Most of the acids have an action on lead; but for this purpose, the sulphuric acid must be concentrated and boiling. Sulphurous acid gas escapes during the solution, and the acid is decomposed. By distilling the solution to dryness, a sulphate of lead is obtained; it is of a white colour, and affords crystals. This sulphate is caustic, and may be decomposed by lime, and the alkalies.

The nitric acid has a strong action upon lead, which, if concentrated, it converts into a white oxide; but if diluted, it dissolves the metal, and forms nitrate of lead, which is crystallizable; lime and the alkalies decompose the nitric solution. Nitrate of lead decrepitates in the fire, and is fused with a yellowish flame upon ignited coals. Sulphuric acid will take lead from the nitric acid, falling down upon being added to it, combined with the metallic oxide. The muriatic acid carries down the lead in the same manner, and forms a muriate of lead formerly called *plumbum corneum*. This is soluble in water.

If nitric acid of the specific gravity of 1.260, be poured upon the red oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown powder. This powder is the brown oxide of lead, it contains 21 per cent. of oxygen.

The muriatic acid, assisted by heat, dissolves a part of the lead put into it, and oxidizes another part. The strong affinity of the oxides of lead for muriatic acid, causes them to decompose almost every substance in which this acid is found, by combining with it. Thus, when volatile alkali is obtained by distilling muriate of ammonia with the oxides of lead, the residuum is muriate of lead: the oxides of lead will even disengage the volatile alkali in the cold. Muriate of soda is decomposed if fused with litharge; the lead uniting as in the last-mentioned case with the muriatic acid, and forming a yellow compound for the manufacture and use of which, as a pigment, a patent has been obtained.

The acetous acid dissolves lead and its oxides. The white oxide of lead, known in commerce by the name of *white lead*, is prepared by its means. The lead is cast in thin plates, which are rolled up in the manner of a watch-spring, with a narrow space between each coil. They are then placed verti-

cally in earthen pots, which contain a quantity of good vinegar, but their lower edge is prevented from coming in contact with the vinegar by suitable projections from the sides of the pots. The pots are then covered, and bedded in tan in a close apartment. The vapour of the acid slowly converts the surface of the lead into a white oxide, which is separated by shaking or uncoiling the plates. The plates are then resubmitted to the same process, until nearly consumed, when they are melted up, and cast over again. The white oxide thus obtained, is prepared for sale by washing it in water, and drying it in the shade: it is then called indiscriminately white lead or ceruse, though some only give the name of ceruse to its mixture with chalk. If white lead be dissolved in the acetous acid, it affords a crystallizable salt or acetite, which, from its sweet taste, is called *sugar of lead.* From its effect in diminishing acidity, sour wines have been sweetened by the addition of white lead, a practice which merits the severest reprobation, as the oxides of lead are the most destructive poisons, in whatever way received into the animal system, whether in solution, by breathing the dust which arises from them, or by working among them with the hands.

The oxides of lead dissolve in oils, of which they correct the rancidity, and therefore they have sometimes been added to the finer oils with fraudulent intentions. Linseed and other drying oils are rendered still more strongly desiccative by boiling upon oxide of lead.

Sulphurets precipitate lead from its solutions, and the sulphur falls down, combined with lead.

Pure alkaline solutions corrode lead, and dissolve a small quantity of it.

Phosphoric acid, if heated with charcoal and lead, becomes converted into phosphorus, which combines with the metal. This phosphuret differs not much from common lead; it is malleable, and easily cut with a knife; but it sooner loses its brilliancy than common lead, and by fusion the phosphorus is burnt, and the lead left pure.

Silver.

Silver is the whitest of all metals, and next to gold it is the most malleable and ductile. Under the hammer, the continuity of its parts is not destroyed until its leaves are not more the $\frac{1}{160000}$ of an inch thick; and it may be drawn into wire finer than a human hair.

The specific gravity of silver is 10.474; its hardness is 6.5; it continues melted at 28° of Wedgwood, but a greater heat is

required to bring it into fusion. Its tenacity is such, that a wire of one-tenth of an inch in diameter, will sustain a weight of 270 pounds, without breaking.

Silver has neither smell nor taste; it is not altered by the contact of air, unless containing sulphurous vapours; but it may be volatilized by an intense heat; and Lavoisier oxidized it by the blowpipe and oxygen gas. By exposing silver twenty times successively to the heat of a porcelain furnace, Macquer converted it into glass of an olive green colour.

Silver is found, in greater or less abundance, in almost all countries which contain mines; but the greatest quantities of it are obtained from the mines of Peru and Mexico. The celebrated mine of Potosi, which is situated near the source of the Rio de La Plata, is in one of the most considerable mountains of Peru, and this mountain is described by travellers as filled with veins of silver from the top to the bottom.

Silver is often found native, in ramifications consisting of octahedrons inserted into each other, also in small intertwined threads, and in masses; but it is most commonly found in combination with sulphur.

Silver forms alloys with most of the metals. Copper is the metal with which it is alloyed for the purpose of coinage. The British coinage contains 11 ounces 2 pennyweights of fine silver in the pound troy. Copper stiffens silver, and increases its elasticity, but it renders it less ductile.

The alloy of silver and zinc is granulated on its surface, and very brittle. Tin, also, in the smallest quantities, deprives silver of its malleability. Alloyed with lead, silver ceases to be sonorous and elastic.

Fine filings of silver, triturated with mercury in a warm mortar, form an amalgam, which, by fusion and slow cooling, affords tetrahedral prismatic crystals, terminated by pyramids of the same form. The mercury cannot be separated from the silver, except by a much stronger heat than would be required to volatilize it alone.

The sulphuric acid dissolves silver, if concentrated and boiling, and the metal in a state of minute division. The action of the muriatic acid upon silver is very trifling, unless oxygenized.

The nitric acid, a little diluted, has a powerful action upon silver, of which it will dissolve half its weight. The solution is at first blue; this colour disappears when the silver is pure; but becomes green if it contained copper. If the silver contains gold, this metal separates in blackish-coloured flocks. The solution is extremely corrosive, and destructive to animal substances. When the acid is fully saturated, it deposits crystals

as it cools, and also by evaporation. These crystals are called lunar nitre, or *nitrate of silver*. By fusion, for which a gentle heat is sufficient, their water of crystallization is driven off; and also a part of the acid, by which they become a subnitrate; this forms the *lapis infernalis*, or lunar caustic of the surgeons; it is of a black colour, and usually cast in the form of small sticks. A heat but little above what is necessary for fusing the nitrate, separates the whole of the acid, and the silver is revived. Lunar caustic should be made of silver entirely free from copper, as the copper is poisonous to wounds.

The cauticity of this and all other mineral solutions, is attributed to the strong propensity of the metal to assume the metallic state; in consequence of which, it readily parts with its oxygen to substances it is in contact with; and therefore such substances as are capable of receiving the oxygen, virtually undergo combustion.

A solution of nitrate of silver in water, is perfectly free from colour; but it stains the skin, and all animal and vegetable substances, an indelible black. It is employed, in a weak state, to dye the human hair, and when mixed with a little gum-water, forms a *permanent ink* for marking linen, see page 783. It is also employed for staining marbles and other stones.

Nitrate of silver is a most powerful antiseptic; a 12,000th part of it dissolved in water will render the water incapable of putrefaction, and it may be separated at any time by adding some common salt.

Silver is precipitated from its solution in nitric acid, by muriatic acid, in the form of a white curd, which, when fused, forms a semi-transparent, and rather flexible mass, resembling horn; it was therefore anciently called *luna cornea*, or *horn silver*, and is supposed to have given rise to some of the accounts we have of flexible glass. It is a *muriate of silver*, soon blackens in the air, and is scarcely soluble in water.

The muriatic acid does not dissolve silver, but has a strong affinity for its oxide, and as the muriate of silver is not very soluble in water, the nitrate of silver is employed as a re-agent, to discover the presence of muriatic acid in any liquid; for if it contain that acid, muriate of silver will fall down in a white cloud, on dropping nitrate of silver into it.

The nitric acid sold in the shops generally contains muriatic or sulphuric acid, or both; hence the nitrate of silver is employed to free the nitric acid from the two latter acids. For this purpose, nitrate of silver is poured into it by degrees, until no more precipitate is produced, after which it is rendered clear, by filtering. Nitric acid thus purified, is called by artists

precipitated aqua-fortis; but it still contains some silver, from which it cannot be freed except by distillation.

When mercury is added to the nitric solution of silver, a precipitation of the silver is formed, which, from its resemblance to vegetation, is called *arbor Dianæ*, or *tree of Diana*.

A few drops of nitrate of silver, laid upon glass, with a copper wire in it, afford another beautiful precipitation of the silver, in the form of a plant.

Silver supplies a fulminating powder, incomparably more dangerous than any other: the nitric solution of fine silver is precipitated by lime-water; the water is decanted; and the oxide is exposed for two or three days to light and air. This dried oxide being mixed with ammonia, or volatile alkali, assumes the form of a black powder; decant the fluid, and leave the powder to dry in the open air. This powder is the fulminating silver, which, after having been once made, can no longer be touched; it must therefore be left in the vessel in which the evaporation was performed. It should never be made but in minute quantities, and not more than the fulmination of a grain should be attempted at once.

The avidity with which sulphur enters into combination with silver, is instanced by Proust, in its tarnishing when exposed in churches, theatres, and other places much frequented by men. This tarnish soon becomes a real crust, which on examination is found to be a sulphuret of silver. It can only be detached by bending the silver, or breaking it to pieces, and its colour is a deep violet, like the sulphuret of silver formed by fusion. Proust is of opinion that sulphur is constantly formed and exhaled by living bodies.

The sulphuret of silver is brittle, and much more fusible than silver. By a sufficient heat alone, the sulphur is volatilized, and the metal entirely recovered.

Nickel.

Nickel is a metal of a grayish white colour, between that of tin and silver; but when not pure it is reddish, which is the colour of its ore. It is both ductile and malleable, when cold and red-hot; its specific gravity is 9.000; and its hardness is 8. It is not fused at a less heat than 150° of Wedgwood.

The ore of the nickel has been long known to the miners of Germany, where, from its resemblance to that of copper, it is called *kupfer-nickel*, or false copper. Bergman was the first who discovered that it contained a peculiar metal.

Nickel is strongly attracted by the magnet, and attracts iron;

on this account it was supposed to contain iron; but Chenevix and Richter discovered that a very small portion of arsenic prevents nickel from being affected by the magnet. When it is not attractable, therefore, the presence of arsenic may be suspected. To separate arsenic from nickel, Chenevix boiled the compound in nitric acid, till the nickel was converted into an arseniate; decomposed this by a nitrate of lead, and evaporated the liquor not quite to dryness. He then poured in alcohol, which dissolved only the nitrate of nickel. The alcohol being decanted and evaporated, he redissolved the nitrate in water, and precipitated by potass. The precipitate, well washed and dried, he reduced in a Hessian crucible lined with lamp-black, and found it to be perfectly magnetic, but this property was destroyed again, by alloying the metal with a small portion of arsenic.

The kupfer-nickel of the Germans, is a sulphuret of nickel, and besides generally contains arsenic, iron, and cobalt. This ore is roasted, to drive off the sulphur and arsenic, then mixed with two parts of black flux, put into a crucible, covered with muriate of soda, and heated in a forge furnace. The metal thus obtained, which is still very impure, may be dissolved in diluted nitric acid, and then evaporated to dryness; after this process has been repeated three or four times, the residuum must be dissolved in a solution of ammonia perfectly free from carbonic acid. Being again evaporated to dryness, it is now to be well mixed with two or three parts of black flux, and exposed to a violent heat in a crucible, for half an hour or more.

Richter says, that pure nickel is not liable to be altered by the atmosphere; hence it is better adapted than steel for compass needles.

By exposing nickel to heat with nitre, an oxide of it is obtained of a greenish colour, if the metal be impure; but if otherwise, brown; this oxide contains 33 parts in the 100 of oxygen.

The French manufacturers of porcelain are said to use the oxide of nickel in producing a delicate grass green. A hyacinthine colour may be given to flint-glass by the same oxide.

Proust observes, that a certain proportion of nickel increases the whiteness of iron, diminishes its disposition to rust, and adds to its ductility. In Birmingham it is occasionally combined with iron and brass. The Chinese also employ it in conjunction with copper and zinc for children's toys. It is the difficulty of working this metal, rather than its scarcity, that renders it so little known. Equal parts of copper and

nickel form a red ductile alloy. The alloys of it with tin and zinc are brittle. Equal parts of silver and nickel form a white ductile alloy. It does not amalgamate with mercury. Nickel is soluble in most of the acids, but the action of the sulphuric and muriatic acids upon it is not considerable. The nitric and nitro-muriatic acids are its proper solvents. The nitric solution is of a fine grass green colour, and by evaporation affords green crystals in rhomboidal cubes.

Cronsted found that nickel combines with sulphur by fusion, and that the result is hard and yellow, with small brilliant facets; but the nickel which he employed was impure.

Nickel combines readily with phosphorus, either by fusion along with phosphoric glass, or by dropping phosphorus upon it while it is red-hot. The phosphuret of nickel is of a white colour, and when broken exhibits the appearance of very slender prisms united together.

It is remarkable that all those bodies called meteoric stones, which have at different times fallen from the atmosphere, contain nickel.

Copper.

Copper is of a pale red colour inclining to yellow. It has a styptic and unpleasant taste, and emits, by friction, a disagreeable smell. Its hardness is 8; its specific gravity 7.788. In point of malleability, it is not much inferior to silver. It is sometimes found native.

If copper be made red-hot, in contact with air, its surface rapidly oxidizes, and the oxide may be separated by the hammer, or by plunging the copper into water; by a repetition of the process another scale will be formed, and this may be continued till the whole of the metal disappears; these scales are a *brown oxide of copper*, which contains 84 parts of copper, and 16 of oxygen. This oxide may be converted into a brown glass by a strong heat.

When exposed to the air, copper becomes covered with a green crust, which is the *green oxide of copper*. This change takes place only at the surface, the oxide itself forming a defence from further change.

Filings of copper thrown upon burning coals, burn with a greenish flame, and when the metal is kept in a greater heat than what is necessary for its fusion, it burns with a flame of the same colour.

Most of the alloys of copper have been already noticed. This metal, with iron, forms the *elderado*, or Keir's patent metal for window-frames, designed to combine elegance and strength.

Copper unites very readily with antimony, and forms an alloy, distinguished by a beautiful violet colour.

Concentrated sulphuric acid dissolves copper by the assistance of heat, and the crystals of the solution, after adding water to it, form a *sulphate of copper*, generally called *blue vitriol*. If to this sulphate of copper be added a solution of arseniate of potass, a beautiful green precipitate is formed, called *Scheele's green*, or *mineral green*. Magnesia, lime, and the fixed alkalies, precipitate copper from its solution in sulphuric acid, in the form of an oxide.

The muriatic acid does not dissolve copper, unless concentrated and in a state of ebullition; the solution is green; the muriatic is caustic and astringent, fuses by a gentle heat, and congeals into a mass.

The nitric acid attacks copper with effervescence. A large quantity of nitrous gas is disengaged. The acid first oxidizes the metal, and then dissolves the oxide. The solution has a blue colour, much deeper than that by the sulphuric acid, and affords crystals by slow evaporation. Lime precipitates the metal of a pale blue; fixed alkalies of a bluish white. Volatile alkali throws down bluish flocks, which are quickly redissolved, and produce a lively blue colour in the fluid.

The acetous acid highly concentrated, dissolves copper; but when not concentrated, it only corrodes the metal, and forms the oxide called *verdigris*. This oxide, dissolved in vinegar, forms a salt called by chemists *crystallized acetite of copper*, and in commerce *distilled verdigris*.

Copper is precipitated from its solutions by iron. The iron is simply immersed in the solution; the acid seizes upon it, and abandons the copper. The copper obtained by this means is called *copper of cementation*. Sulphate of copper is frequently found in the streams of water from copper-mines; the quantity of salt which they contain is not sufficient to reimburse the expense of evaporating the water to obtain blue vitriol; but by throwing waste pieces of iron into them, the salt is decomposed, and the copper is precipitated in a metallic form, because the sulphuric acid has a greater attraction for iron than copper. It appears in effect as if the iron were changed into copper, and to the superficial observer favours the idea that metals are transmutable. The streams of mines thus containing sulphate of copper are often as valuable as the ore itself.

All the salts of copper are poisonous; and copper vessels should therefore never be used to contain any vehicle capable of holding the metal in solution. In Sweden, the use of copper vessels for culinary purposes, has been prohibited by law, and a

statue of the metal dedicated to the man at whose solicitation it was obtained.

Sulphur combines with copper at a strong heat. Sulphuret of copper is brittle, softer than copper, of a black colour externally, and within of a leaden grey.

A *phosphuret of copper* may be formed by casting phosphorus upon red-hot copper. It has the hardness of steel, but is too brittle and refractory to be useful.

Prussic acid unites with the oxide of copper, and forms a brown pigment, superior, both in oil and water, according to the experience of Hatchet, to any other in use. It has a purple tinge, so as to form various shades of bloom or lilac when mixed with white, and which are not so liable to fade as those made with lake. The best mode of preparing the prussiate of copper, is to dissolve the green muriate in ten parts of distilled water, and precipitate with prussiate of lime.

Fixed alkalies have some action on copper, with which they form a light blue solution; the effect is greatest in the cold.

Ammonia dissolves copper with much greater rapidity than fixed alkalies, whether it be in the state of a metal or an oxide, and forms a beautiful blue solution. This solution, when recently made, is colourless if the vessel be closed, but when the vessel is opened, the colour returns, gradually extending from the surface downwards.

Oils appear to have no action on copper, until they become rancid; in which case their disengaged acid corrodes the copper, and the oil assumes a bluish green colour.

Iron.

Iron is of a bluish white colour, highly elastic, sonorous, has a styptic taste, emits a peculiar odour when rubbed, and strikes fire with flint. In tenacity it exceeds all metals; a wire of it, only one-tenth of an inch in diameter, sustaining a weight of 450 pounds without breaking. Its specific gravity is 7,788.

Iron is less malleable than gold, silver, or copper; it is of all the metals in common use the most difficult of fusion, but the nearer it approaches to fusion, the more malleable and ductile it becomes.

The hardness of iron, its great tenacity, the facility with which it may at a white heat be fashioned and welded, are the properties which render it so valuable.

Iron is attracted by the magnet or loadstone, and is itself capable of being rendered magnetic; but this property, after having been communicated to it, is retained only a short time, unless it be in the state of hard steel.

If suddenly plunged into cold water, while red-hot, it is rendered rather more rigid than before, but gradual cooling renders it soft.

Iron is sometimes found native. In the museum of the academy of sciences at Petersburgh, is a mass of native iron 1200 tons in weight.

Cast-iron is that which results from the fusion of the iron ore with charcoal; its peculiar properties are owing to its containing carbon and other foreign matters.

Steel is iron deprived of all impurities except a small portion of carbon; it is more ductile than iron, and a finer wire may be drawn from it than any other metal.

Iron, united with about nine-tenths of charcoal, forms plumbago, or hyper-carburet of iron.

Iron has a greater affinity for oxygen than oxygen has for hydrogen; it therefore decomposes water by combining with its oxygen, which is the cause of its being so easily altered by exposure to damp air, or to water.

The action of air, assisted by heat, converts a thick pellicle of the surface of iron into a black oxide, containing 25 per cent. of oxygen, and when this is hammered off, another is quickly formed. This black oxide is attracted in some degree by the magnet. If it be collected, and exposed to a strong heat under a muffle, it becomes a reddish brown oxide, containing 48 per cent. of oxygen. The yellow rust, formed when iron is long exposed to damp air, is not a simple oxide, but contains a portion of carbonic acid. Proust only admits two stages in the oxidation of iron, viz. the green and the brown or red, and considers the other supposed oxides, to be mixtures of these in various proportions.

The *green oxide* may be obtained by dissolving iron in sulphuric acid, and then precipitating it by potass; this oxide contains 27 parts of oxygen, and 73 of iron in the 100. By exposure to the air, it is converted into the brown oxide, which contains 18 parts of oxygen, as observed above.

Concentrated sulphuric acid scarcely acts on iron, unless it be boiling; but if diluted with two or three times its weight of water, it attacks the metal immediately, and a strong effervescence ensues, without any heat but that produced by the addition of the water. It is the hydrogen gas of the water which escapes, the oxygen being employed in oxidizing the metal, which oxide the acid dissolves without being decomposed. If heat be applied, more iron still is dissolved. This solution yields, by evaporation, *sulphate of iron*. The common green copperas of commerce is this salt in a state of impurity. It is much more soluble in hot than in cold water, and therefore

a saturated solution of it in hot water affords crystals in cooling as well as by evaporation.

The substance called *martial pyrites* is a sulphuret of iron, and it is from the decomposition of it that the extensive demand for sulphate of iron is supplied. By fusion with iron, sulphur produces a compound of the same nature as pyrites.

The sulphuret of iron, as well as iron itself, burns rapidly, but without noise, when triturated in a metallic mortar with hyper-oxymuriate of potass; this mixture, in a heap, if struck with steel, detonates strongly, and gives out a red flame.

Sulphate of iron is decomposed by alkalies and by lime. Caustic fixed alkali precipitates the iron in deep green flocks, which are dissolved by the addition of more alkali, and form a red tincture. The mild alkali does not redissolve the precipitate it throws down, which is of a greenish white colour. Distillation separates the acid from sulphate of iron, and leaves the brownish red oxide, called *colcothar*.

Astringent vegetables, such as gall-nuts, oak, tea, &c. precipitate a fine black fecula from sulphate of iron, and this precipitate remains suspended a considerable time in the fluid by the addition of gum-arabic, and hence its utility as a writing ink. The well-known pigment called Prussian blue, is likewise a precipitate afforded by sulphate of iron.

Sulphur combines with iron merely by the assistance of water; thus if flowers of sulphur be mixed with iron filings, and made into a paste with water, it soon becomes hot, swells, and emits the well-known smell of hydrogen, with watery vapours. The mixture takes fire, if in considerable quantity, even although buried in the earth. It is a composition, therefore, which may be used to form an artificial volcano.

Concentrated nitric acid is rapidly decomposed by iron, a portion of the oxygen of the acid oxidizes the iron, which oxide dissolves as it is formed, and the remainder of the acid passes off in nitrous gas. The solution is of a reddish brown, and deposits the oxide of iron after a certain time, particularly if exposed to the air. Diluted nitric acid affords a more permanent solution of iron, of a greenish colour, or sometimes of a yellow colour. Neither of the solutions afford crystals, but both deposit the oxide of iron by boiling, at the same time that the fluid assumes a gelatinous appearance. This magma, by distillation, affords fuming nitrous acid, much nitrous gas, and some nitrogen, a red oxide being left behind.

Iron appears to be the only metal of which the solutions, or combinations with oxygen, are not of a noxious nature. The chalybeate waters form the best tonics which medicine possesses.

The muriatic solution of iron, like all other solutions of the same metal, is decomposed by lime and alkalies; but the precipitates are less altered, and may be easily reduced, especially such as are produced by the addition of caustic alkalies. Alkaline sulphurets, sulphuretted hydrogen gas, and astringents, also decompose this as well as the other solutions of iron.

Water charged with carbonic acid dissolves a considerable quantity of iron. Vinegar appears to have little or no effect upon iron, unless assisted by the air.

If equal parts of iron clippings, and phosphoric glass, be melted together, a phosphuret of iron is obtained, which is very brittle, and has a whitish fracture. Iron, in its crude state, frequently contains phosphorus, which renders cast-iron very refractory, and forms the kind called *cold-short iron*, which is malleable when hot, though brittle when cold.

Gold unites easily with iron, and becomes by this union harder and less malleable. In the proportion of six parts of gold and one of steel, the alloy may be beaten into plates without cracking. The iron is only partially separated by combustion in a glowing heat. Iron has a stronger attraction than gold for the oxy-muriatic and nitro-muriatic acids, and precipitates gold from these acids in its metallic state.

Silver combines readily with iron. A mixture of fourteen parts of silver, and two and a half iron, is more elastic than silver, attracts the magnet, and is not decomposed in a strong fire. A small portion of iron does not seem to injure the colour or malleability of the silver. Iron precipitates silver from all its solutions in acids; but this happens in the nitric only, when the acid is not completely saturated, or when nitrous gas is added. Muriate of silver is decomposed in the dry way by distillation with iron filings.

Iron precipitates mercury in its metallic state from its solution in acids. Distilled with oxy-muriate of mercury, the muriate is decomposed, and fluid mercury produced.

Sulphate of iron precipitates mercury from its solution in nitric acid, in its metallic state.

Lead is precipitated from its solutions in acids by iron. Iron also precipitates nickel from its acid solutions, and in the dry way takes from it the sulphur which it contains.

Nickel has the strongest affinity of all the metals for iron, and is separated from it with the greatest difficulty. The alloy is fully as malleable, but less fusible than iron alone. Nickel is precipitated only in a very imperfect manner by iron from its solutions in acids.

Iron unites in close vessels with arsenic, which renders it more brittle, diminishes its attraction for the magnet, and is separated from it with difficulty.

When iron has been covered with a coat of tin, the tin appears to combine with it, and forms an alloy of greater depth than would readily be supposed; even a white heat is insufficient to separate the tin entirely, yet till the whole of it is removed, the iron will not weld.

Tin.

Tin is a white metal, intermediate between that of lead and silver; it has little elasticity; its taste is disagreeable, and it has a peculiar smell, which increases by friction. Its hardness is 6; its specific gravity 7.291, and its density, it will be seen by inspecting the table of specific gravities, is susceptible of very little increase by hammering. Its purity is judged of by its levity, as it cannot be alloyed with any metal lighter than itself.

The malleability of tin is such, that it may be extended into leaves not more than the 2000dth part of an inch thick; the tin-leaf, called *tin-foil*, is, however, twice this thickness. The tenacity of tin is but small: a wire, one-tenth of an inch in diameter, will support only about 49 pounds without breaking. Its flexibility is considerable; it may be bent several times backwards and forwards without breaking, emitting at the same time a distinct crackling noise.

All the tin used in England is supplied by the mines of Cornwall, which furnish 3000 tons annually. Its ores occur most frequently in granite, but never in limestone. It is very rarely found native.

Chaptal says, that if tin be kept in fusion in a lined crucible, and the surface be covered with a quantity of charcoal to prevent its calcination, the metal becomes whiter, more sonorous, and harder, provided the fire be kept up for eight or ten hours.

The brilliant surface of polished tin soon becomes a little tarnished by exposure to the air, but the effect is very superficial and slight.

Mercury dissolves tin with great facility, and in all proportions. To make this combination, heated mercury is poured on melted tin; the consistence of the amalgam differs according to the relative proportions of the two metals.

Nickel united to tin, forms a white and brilliant mass. Half a part of tin, melted with two parts of cobalt, and the same quantity of muriate of soda, furnished Beaume with an alloy in small close grains of a light violet colour.

Equal parts of tin and bismuth, form a brittle alloy, of a medium colour between the two metals, and the fracture of which presents cubical facets.

Zinc unites perfectly with tin, and produces a hard metal, of a close-grained fracture; its ductility increases with the proportion of tin.

Antimony and tin form a white and brittle alloy, which is distinguished from other alloys of tin by its possessing a less specific gravity than either of the two metals by which it is formed.

In combining arsenic with tin, precautions must be taken to prevent the arsenic from escaping by volatilization. Three parts of tin may be put into a retort, with one-eighth part of arsenic in powder; fit on a receiver, and make the retort red-hot; very little arsenic rises, and a metallic lump is found at the bottom, containing about one-fifteenth part of arsenic; it crystallizes in large facets, is very brittle, and hard to melt.

If tin be kept in fusion with access of air, its surface is speedily covered with a grayish pellicle, which is renewed as fast as it is removed. If this gray oxide be pulverized and sifted, to separate the uncalcined tin, and calcined again for several hours, under a muffle, it becomes the yellow oxide of tin, called among artizans *putty of tin*, and extensively used in the polishing of glass, steel, and other hard bodies.

A white oxide of tin is used in forming the opake kind of glass called enamel. This composition is made by calcining 100 parts of lead, and 30 parts of tin, in a furnace, and then fluxing these oxides with 100 parts of sand, and 20 of potass. This enamel is white, and is coloured with metallic oxides.

All the mineral acids dissolve tin, and it may be precipitated from its solutions by potass; but an excess of potass will redissolve the metal. Nitro-muriate of gold is a test for tin in solution, with which it forms a fine purple precipitate.

The sulphuric acid dissolves tin, whether concentrated or diluted with water; part of the acid is decomposed, and flies off in the form of sulphurous acid gas. Heat accelerates the effect of the acid. Tin dissolved in the sulphuric acid is very caustic.

The solution of tin in the nitric acid is performed with astonishing rapidity; and the metal is precipitated almost instantly in the form of a white oxide. If this acid be loaded with all the tin it is capable of calcining, and the oxide be washed with a considerable quantity of distilled water, a salt may be obtained by evaporation, which detonates alone in a crucible well heated, and burns with a white and thick flame,

like that of phosphorus. The nitric acid holds but a very small quantity of tin in solution, and when evaporated for the purpose of obtaining crystals, the dissolved portion quickly precipitates, and the acid remains nearly in a state of purity. Nitric acid much diluted, holds rather more tin in solution, but lets it fall by standing, or by the application of heat.

The muriatic acid dissolves tin, whether cold or hot, diluted or concentrated. If fuming, and assisted by a gentle heat, the addition of the tin instantly causes it to lose its colour and property of emitting fumes, and a slight effervescence takes place. The acid dissolves more than half its weight of tin; the solution is yellowish, of a fetid smell, and affords no precipitate of oxide, like the sulphuric and nitric acids.

The oxymuriatic acid dissolves tin very readily, and without effervescence, because the metal quickly absorbs the superabundant oxygen from the acid, and requires no decomposition of the water to effect its oxidation.

Nitro-muriatic acid, made with two parts of nitric acid and one of muriatic acid, dissolves tin with effervescence. It is the solution of tin in this acid which the dyers employ to heighten the colour of their scarlet dyes. It is prepared by adding small portions at a time of tin to the common aqua-fortis of commerce; when the appearance of oxide is observed at the bottom of the jar, muriate of soda is added, by which its solution is effected. If the colour imparted by this solution is not bright, a little nitrate of potass is added to it.

The acetous, and most other vegetable acids, have some action upon tin, particularly when aided by a gentle heat; but the solutions thus obtained, are not used in the arts.

Tin decomposes the corrosive muriate of mercury. It is for this purpose amalgamated with a small portion of mercury, and this amalgam, being first triturated in a mortar with the corrosive muriate, the mixture is then distilled by a gentle heat. A colourless liquor first passes over, and is followed by a thick white vapour, which issues with a kind of explosion, and covers the internal surface of the receiver with a very thin crust. The vapour becomes condensed into a transparent liquor, which continually emits a thick, white, and very abundant fume. It was formerly called the *fuming liquor of Libavius*, and is the combination of the muriatic acid and tin.

Tin has a strong affinity for sulphur; the sulphuret of tin may be formed by fusing the two substances together; it is brittle, heavier than tin, and not fusible. It has a bluish colour, a lamellated texture, and is capable of crystallizing.

The white oxide of tin combines with sulphur, and forms

a compound called *aurum musivum*, or *mosaic gold*, which is much used for giving plaster of Paris the resemblance of bronze, and improving the appearance of bronze itself. It is also occasionally used to increase the effects of electrical machines. Chaptal recommends for preparing it the process of the Marquis de Bouillon, who directs an amalgam to be formed of eight ounces of tin and eight ounces of mercury. In forming the amalgam, a copper mortar is heated, and the mercury poured into it, after which the tin is added in a state of fusion, and the mixture triturated till cold. Six ounces of sulphur and four ounces of muriate of ammonia, are then mixed, and the whole put into a matrass, which is to be placed in a sand-bath, and heated to such a degree as to cause a faint ignition in the bottom of the matrass. The fire must be kept up for three hours. The aurum musivum obtained by this process is usually excellent; but if, instead of placing the matrass on the sand, it be immediately exposed upon the coals, and strongly and suddenly heated, the mixture will take fire, and a sublimate will be formed in the neck of the vessel, which consists of the most beautiful aurum musivum that can be prepared.

The mercury and muriate of ammonia are not in strictness necessary to the production of aurum musivum. Eight ounces of tin dissolved in the muriatic acid, precipitated by the carbonate soda, and mixed with four ounces of sulphur, will produce a fine aurum musivum, but without the property of exciting electrical machines.

A phosphuret of tin may be formed by melting in a crucible equal parts of tin and phosphoric glass, or by throwing small pieces of phosphorus into melted tin. The phosphuret of tin may be cut with a knife; it extends under the hammer, but separates into lamina. When newly cut, it has the colour of silver; its filings resemble those of lead, and the phosphorus takes fire when they are thrown upon burning coals.

Zinc.

Zinc is a bluish white metal; its specific gravity is 7.190; its hardness 6. It is distinguished by the singular property of being neither malleable nor ductile, at common temperatures, but of acquiring both these qualities at the temperature of 210° to 300°. It has neither taste nor smell. It melts at the heat of about 700.

Zinc, at a red heat, burns with a bright white flame, and throws out white flakes, called *flowers of zinc*. These flowers

are the white oxide of the metal; they are not volatile, but are merely driven off by the force of the combustion. They contain more oxygen than the gray oxide, which forms on the surface of the metal when it is heated to fusion. The white oxide of zinc may be converted into a yellow glass by a very violent heat.

Zinc combines with most of the metals. With gold it combines in all proportions. The alloy is very hard and white when the metals are in equal proportions, and takes a fine polish, without being very liable to tarnish. One part of zinc is said to destroy the ductility of 100 parts of gold.

The alloy of silver and zinc is also brittle. Platina unites with zinc, and forms a brittle and fusible alloy, tolerably hard, and of a bluish white colour, not so clear as that of zinc.

One part of zinc, and two and a half of mercury, form by fusion an amalgam which becomes solid. It is used to excite electrical machines.

The well-known alloy called brass, which is formed of zinc and copper, is usually formed by cementing copper in a close crucible with calamine, an ore which contains zinc in the state of an oxide.

Tin and zinc combine readily, the alloy is harder than tin. Lead and zinc also form alloys which are harder than lead. Two parts of lead and three of zinc form a hard alloy, which bears hammering without extending.

Iron and zinc have some affinity, as iron may be coated with zinc instead of tin, for culinary vessels. The solutions of zinc which may happen to be obtained, are not dangerous like those of lead.

If water be thrown upon ignited zinc, part of it is decomposed: the oxygen converts part of the metal into an oxide, and hydrogen gas escapes.

Sulphuric acid dissolves zinc without heat. A salt may be obtained by evaporating the solution; this salt, which is a sulphate of zinc, is known by the name of white vitriol; it has a strong styptic taste.

The nitric acid powerfully attacks zinc, and produces much heat; a great part of the acid is decomposed; but crystals may be obtained by the slow evaporation of the residue. This salt, or nitrate of zinc, is deliquescent; it melts upon heated coals, and decrepitates, producing a slight reddish flame. If it be exposed to heat in a crucible, it emits red vapours, assumes the consistence of a jelly, and preserves this softness for a considerable time. The nitric solution of zinc is very caustic.

Muriatic acid also acts strongly upon zinc, with the disengagement of much hydrogen gas. The solution, by evaporation, does not crystallize, but assumes the consistence of jelly. This jelly, if distilled, allows some of the acid to escape, and part of the muriate sublimes.

Most of the metallic and vegetable acids dissolve zinc, which is precipitated from its solutions by earths and alkalies; the latter re-dissolve the precipitate, if added in excess.

Sulphur cannot be made to combine with metallic zinc; but it combines readily with the oxide of zinc.

Zinc may be combined with phosphorus by casting small pieces of phosphorus upon the melted metal, which should be covered with tallow or resin to prevent its oxidation. Phosphuret of zinc is white, with a shade of bluish gray, has a metallic lustre, and is a little malleable.

Zinc also combines with carbon, and forms a carburet of zinc. It generally contains a small portion of carbon.

Potassium.

The fixed alkalies, potass and soda, are found not to be simple bodies, as had once been supposed, but oxides, each of them containing a peculiar metal in combination with oxygen. They were analyzed by Sir Humphrey Davy, in a course of experiments which that distinguished chemist undertook with the express view of discovering their nature. He succeeded by means of the galvanic apparatus in the following manner:

In his first experiments he acted upon aqueous solutions of potass and soda, by a powerful Voltaic combination, but in this way he only obtained the decomposition of the water of the solution. He then acted upon these alkalies in a state of igneous fusion. The potass was contained in a platina spoon, and was kept perfectly fused, in a strong red heat, by means of a stream of oxygen gas, from a gazometer applied to the flame of a spirit lamp. The spoon was preserved in communication with the positive side of a battery of the power of 100 plates of 6 inches, highly charged, and the connection from the negative side was made by a platina wire. The advantage of this arrangement over the aqueous solution was soon apparent. The potass appeared to be a conductor in a high degree, and as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which seemed to be owing to the development of combustible matter, arose from the point of contact. When the order was

changed, so that the platina spoon was made negative, a vivid and constant light appeared at the opposite point; there was no effect of inflammation round it; but aëriform globules, which inflamed in the atmosphere, rose through the potass.

As the products of the decomposition, which evidently appeared to have taken place in the above experiment, could not be collected, Sir H. Davy determined to apply the galvanic electricity to the alkali in its usual state. A small piece of potass, moistened a little by the breath, was placed upon an insulated disc of platina, connected with the negative side of a battery, consisting of 100 plates of 6 inches, and 150 of 4 inches square, in a state of intense activity, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open air. Under these circumstances, a vivid action was soon observed to take place. The potass began to fuse at both its points of electrization, and small globules, having a high metallic lustre, and precisely similar in visible characters to mercury, appeared, some of which burnt with explosion and bright flame. These globules are the basis of potass, which has received the name of *potassium*, and appears fully entitled to rank among the metals, as we shall proceed to shew.

It next became a matter of considerable difficulty to preserve and confine the basis of potass, in order to examine its properties. Sir H. Davy found, however, at length, that in recently distilled naphtha it may be preserved for some days, and that its physical properties may easily be examined in the atmosphere, when it is covered with a thin film of this fluid.

Potassium, at the temperature of 60°, is only imperfectly fluid; at 70° it becomes more fluid; and at 100° its fluidity is perfect, so that different globules may be easily made to run into one. At 50° it becomes a soft and malleable solid, which has the lustre of polished silver; at about the freezing point of water, it becomes hard and brittle, and when broken in fragments, exhibits a crystallized texture, of perfect whiteness and high metallic splendour. To be converted into vapour, it requires a temperature approaching to that of a red heat. It is an excellent conductor of caloric and of electricity.

Potassium will not sink in doubly distilled naphtha, the specific gravity of which is .770. Its specific gravity is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10, so that it is the lightest fluid body known. Its levity is the physical property in which it differs most materially from the rest of the metals; yet between the lightest and heaviest of the established metals, the difference

is not much less, than between the lightest of the established metals and potassium.

When potassium is introduced into oxymuriatic acid gas, it burns spontaneously with a bright red light, and muriate of potass is formed. When thrown upon water, it decomposes it with great violence, an instantaneous explosion is produced with a brilliant flame, and a solution of pure potass is the result. When a globule is placed upon ice, not even the solid form of the two substances can prevent their union; for it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potass. When a globule is dropped upon moistened turmeric paper, it instantly burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace.

So strong is the attraction of the basis of potass for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified.

When potassium is thrown into the mineral acids, it inflames and burns on the surface. In sulphuric acid, sulphate of potass is formed; in nitrous acid, nitrous gas is disengaged, and nitrate of potass formed. When pressed upon a piece of phosphorus, there is a considerable action; the two substances become fluid together, burn, and produce phosphate of potass.

When a globule of potassium is made to touch a globule of mercury, about twice as large, they combine with considerable heat; the compound is fluid at the temperature of its formation; but when cool, it appears as a solid metal, similar in colour to silver. If this alloy be exposed to the air, it rapidly absorbs oxygen; potass which deliquesces is formed, and in a few minutes the mercury is found pure and unaltered. When a globule of the amalgam is thrown into water, it rapidly decomposes it with a hissing noise, potass is formed, hydrogen disengaged, and the mercury remains free.

The amalgam of potassium and mercury dissolved all the metals that were exposed to it; and in this state of union, mercury acts on iron and platina.

Potassium combines with fusible metals, and the alloy has a higher point of fusion than the fusible metal.

Potassium readily reduces the metallic oxides, when heated in contact with them. It decomposes common glass by a gentle heat, and at a red heat effects a change even in the purest glass.

From a variety of experiments, Professor Davy concludes,

that 100 parts of potass, consist of about 84 basis, and 16 oxygen.

Sodium.

When soda is exposed to the action of galvanic electricity, in the same manner as the potass, in the experiment above stated, a metal is obtained which is the basis of the alkali, and is called *sodium*.

Sodium is white, opake, and, when examined under a film of naphtha, has the lustre and general appearance of silver. It is exceedingly malleable, and is much softer than any of the common metallic substances. A globule of it only one-tenth or one-twelfth of an inch in diameter, is easily spread over a surface of a quarter of an inch, and this property does not diminish when it is cooled to 32° of Fahrenheit.

By strong pressure, globules of sodium may be made to adhere and combine into one mass; so that the property of welding, which belongs to iron and platina at a white heat only, is possessed by this substance at common temperatures.

Sodium conducts caloric and electricity in a similar manner to potassium; and small globules of it inflame by the Voltaic electrical spark, and burn with bright explosions. It is preserved under distilled naphtha in the same manner as potassium.

Its specific gravity is somewhat less than that of water, being as .9348 to 1. It is therefore heavier than potassium, but the difference is so small that we place them in the order in which they were discovered.

Sodium has a much higher point of fusion than potassium; its parts begin to lose their cohesion at about 120°, and it is a perfect fluid at about 180°, so that it readily fuses under boiling naphtha. But though so easily fused, it remains in a state of ignition at the point of fusion of plate glass.

The chemical phenomena of sodium are not very different from those of potassium. When exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust, which deliquesces much more slowly than that furnished by potassium.

The flame that sodium produces in oxygen gas is white, and it sends forth bright sparks, occasioning a very beautiful effect; in common air it burns with light of the colour of that produced during the combustion of charcoal, but much brighter.

When introduced into oxymuriatic acid gas, it burns vividly, with numerous scintillations of a bright red colour.

The substance produced by this combustion is muriate of soda (common salt.)

When thrown upon water, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygen of the water to form soda, and the hydrogen of the water is disengaged. This experiment exhibits no luminous appearance. With hot water, the decomposition is more violent, and a few scintillations are observed at the surface of the fluid; but this is owing to small particles of sodium which are thrown out of the water sufficiently heated to burn in passing through the atmosphere.

Sodium decomposes the water of alcohol and ether, in the same manner as the water in these fluids is decomposed by potassium.

It acts upon strong acids with great energy. With nitrous acid, a vivid inflammation is produced; with muriatic and sulphuric acid there is much heat but no light.

Sodium, in its action on sulphur, phosphorus, and the metals, scarcely differs from potassium. It combines with sulphur in close vessels filled with the vapour of naphtha, with a vivid light, heat, and often with explosion. The sulphuret is of a deep gray colour.

The phosphuret has the appearance of lead, and forms phosphate of soda by exposure to air, or by combustion.

One-fortieth part of sodium renders mercury a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat.

It makes an alloy with tin without changing its colour, and it acts upon lead and gold when heated. In its state of alloy, it is soon converted into soda by exposure to the air.

Sir H. Davy concluded, that 100 parts of soda consist of 76 or 77 sodium, and 24 or 23 oxygen.

In concluding the communication to the Royal Society, from which the preceding view of the properties of potassium and sodium is derived, Sir H. Davy justly remarks, that an immense variety of objects of research is presented in the powers and affinities of the new metals produced from the alkalies. In themselves they will undoubtedly prove powerful agents for analysis; and having an affinity for oxygen stronger than any other known substances, they may possibly supersede the application of electricity to some of the undecompounded bodies.

In sciences kindred to chemistry, the knowledge of the nature of the alkalies, and the analogies arising in consequence, will open many new views; they may lead to the solution of many problems in geology, and shew that agents

may have operated in the formation of rocks and earths which have not hitherto been suspected to exist.

Bismuth.

Bismuth is known among artisans by the name of *tinglass*. It is a metal of a laminated texture, a pale yellowish red colour; not ductile or malleable, but reducible to powder under the hammer. Its specific gravity is 9.822; its hardness is 6. It melts at the heat of 460°.

Bismuth sublimes when heated in close vessels; when allowed to cool slowly, it crystallizes. It is not altered by water, and though it tarnishes by exposure to the air, it is not much changed.

Bismuth combines with most of the metals; its general effects is to increase their fusibility. The alloy of bismuth and platina is very brittle. When exposed to the air, it assumes a purple, violet, or blue colour. The bismuth may be separated by heat.

Equal parts of bismuth and gold form a brittle alloy, not much paler than gold.

Equal parts of bismuth and silver also form a brittle alloy, but less so than the last. The specific gravity of this and the last alloy is greater than intermediate.

The amalgam of mercury and bismuth is more fluid than pure mercury, and has the property of dissolving lead, without having its fluidity lessened.

The alloy of copper and bismuth is not so red as copper.

A small portion of bismuth renders tin brighter, harder, and more sonorous: it is often therefore an ingredient in pewter. Bismuth remarkably increases the fusion of this metal: when the alloy consists of equal parts, it melts at 280°.

Bismuth does not combine with zinc, and its alloy with iron, cobalt, arsenic, and antimony, is unknown.

The alloy of lead and bismuth is of a dark gray colour, a close grain, and very brittle. The fusibility of a compound of tin, lead, and bismuth, has been pointed out in volume I. page 44.

Bismuth expands as it cools, for which reason it is well adapted for casting, and is sometimes added in the composition for printers' types, particularly the smaller sizes, where a sharp perfect impression from the mould is of great importance.

Bismuth may be used in cupellation instead of lead, and would for this purpose be preferable to lead, were it not so much more scarce and expensive.

This metal, when exposed to a red heat, burns with a faint blue flame, and emits yellowish fumes, which when condensed, form what are called *flowers of bismuth*. This oxide is converted into a greenish glass by a strong heat.

The sulphuric acid, when concentrated and boiling, has a slight action upon bismuth. Sulphurous acid gas escapes, and part of the metal is converted into a white oxide. The sulphate of bismuth does not crystallize, and is very deliquescent.

The nitric acid exerts a vehement action on bismuth. Much heat, with a large quantity of nitrous gas, is evolved. The solution, when saturated, affords crystals as it cools. This nitrate detonates weakly, and leaves a yellow oxide behind, which effloresces in the air.

The action of the muriatic acid upon bismuth is very slow and inconsiderable, and even for this effect the acid must be highly concentrated.

Water precipitates bismuth from all its solutions; the precipitate, which is a beautiful white, is, when well washed, used as a cosmetic, under the name of magistery of bismuth. It has, however, the disadvantage of turning to a dark colour, by a very slight degree of sulphurous effluvia, and as the metal resembles lead in its noxious qualities, and is seldom free from arsenic, like other mineral cosmetics, it cannot be used without danger to the skin and the constitution.

Magistery of bismuth is sometimes mixed with pomatum, for the purpose of staining the hair of a dark colour.

Sulphur combines readily with bismuth by fusion. The sulphuret of bismuth is of a bluish gray colour, and crystallizes into beautiful tetrahedral needles. It contains 15 parts in the 100 of sulphur.

Phosphorus dropped into melted bismuth, forms a phosphuret of the metal, which only contains about 4 parts in the 100 of phosphorus.

Arsenic.

Arsenic is of a brilliant bluish white colour, a laminated texture, friable, and very brittle. Its specific gravity is 8.310, its hardness 7. It soon tarnishes by exposure to the air, becoming first yellowish, and then black; but if immersed in alcohol, its metallic lustre suffers no diminution. It is one of the most combustible metals, burns with a blue flame, and the smell of garlic, and sublimes in the state of arsenious acid. It is, in all states, one of the most virulent poisons known.

When exposed to the air, arsenic is gradually converted by combining with oxygen, into a grayish black substance, which is the *gray oxide of arsenic.* If this oxide be sublimed, the sublimate having combined with an additional dose of oxygen, forms the *white oxide of arsenic*, which contains 7 parts in the 100 of oxygen. This oxide glitters as if it were powdered glass; it has an acid taste, which terminates in an impression of sweetness; it has a smell like garlic. This is the state in which the arsenic of commerce is met with.

The white oxide of arsenic may be converted into the metallic state by heating it with oils, tallow, or charcoal, in close vessels; but this is seldom necessary in the arts, as it enters into combination with other metals from the state of oxide. This oxide is soluble in 80 parts of water, at the temperature of 60°, and in 15 parts of boiling water. When the solution is evaporated, the oxide crystallizes; and when heated to 283° it sublimes; if heated in close vessels, it becomes pellucid like glass, but soon recovers its former appearance by exposure to the air. The specific gravity of the glass is 5.000; of the white oxide 3.706.

Almost the whole of the arsenic which is sold, is obtained from the cobalt ores of Saxony, where long winding flues are constructed, to the sides of which the sublimed arsenic attaches itself.

Arsenic unites with most of the metals by fusion, and a very small quantity of it has often a material effect.

Platina and arsenic form a brittle and fusible alloy; the arsenic may be driven off by a great heat.

Gold by fusion takes up about $\frac{1}{15}$th of arsenic, with which it forms a pale and brittle alloy.

Silver takes up one-fourteenth of arsenic.

Copper combines with five-sixths of arsenic, forming a white, hard, and brittle alloy; when the quantity of arsenic is small, it is both ductile and malleable; it is called *white tombac*, and is much used in the manufacture of buttons.

Iron is capable of combining with more than its own weight of arsenic; the alloy is white, brittle, and capable of crystallizing.

The alloy of tin and arsenic is harder and more sonorous than tin, and has nearly the same external appearance as zinc. Tin often contains a small quantity of arsenic.

Lead takes up one-sixth of arsenic. The alloy is brittle and dark coloured.

Zinc takes up one-fifth of arsenic, antimony one-eighth, and bismuth one-fifteenth.

Upon the whole, the effect of arsenic is, to whiten the red and dark-coloured metals; to give brittleness to the ductile; to increase the fusibility of the refractory; and to render less fusible the rest. It is added to the composition for the mirrors of reflecting telescopes, to increase the density of the compound.

The sulphuric acid, boiled on the oxide of arsenic, dissolves it; but the oxide is precipitated as the solution cools.

The nitric acid dissolves the oxide of arsenic, by the assistance of heat, and forms a deliquescent salt.

The action of the muriatic acid upon arsenic is very feeble, whether assisted by heat or in the cold. The sublimed muriate or butter of arsenic, is formed by mixing equal parts of the yellow oxide of arsenic, and corrosive muriate of mercury, and distilling with a gentle heat; in the receiver will be found a blackish corrosive liquor, which forms the sublimed muriate of arsenic.

Potass, boiled on the oxide of arsenic, becomes brown, gradually thickens, and at last forms a hard brittle mass, which is a deliquescent arsenical salt. Soda affords, by the same treatment, a product nearly similar.

The combination of arsenic and sulphur is often found native, of a fine yellow colour; it is then called *orpiment;* this yellow sulphuret of arsenic may be prepared artificially, by mixing sulphur with the white oxide of arsenic, and heating them. It contains about 20 parts of arsenic in the 100. If a stronger heat be applied, so as to fuse this sulphuret, it assumes a scarlet colour, and forms the compound called *realgar*, which contains 80 parts of arsenic in the 100. It is the red sulphuret of arsenic. Realgar is occasionally found native, as well as orpiment. Lime and the alkalies decompose these sulphurets.

The phosphuret of arsenic may be formed by putting equal parts of phosphorus and arsenic into a sufficient quantity of water, and keeping the mixture moderately hot for some time. It is black and brilliant, and ought to be preserved in water.

The oxide of arsenic promotes the vitrification of earths, but the glasses into which it enters are liable to tarnish.

The workmen employed in the mines which produce arsenic, are subject to violent complaints, and a premature death. When this deleterious mineral has been swallowed, the sulphuret of potass (liver of sulphur) dissolved in water, is prescribed as the most effectual antidote. Arsenic, whether alone or in a mixture, may be distinguished by throwing it upon burning coals; as it will afford white fumes and the smell of garlic.

Antimony.

Antimony is a brittle metal, of a white colour inclining to gray, a laminated texture, exceedingly brittle, and neither malleable nor ductile. It may be reduced to powder. It has some taste, but no smell. Its specific gravity is 6.860; its hardness 6.5. It tarnishes but little by the action of air or water. It melts at a low red heat, or 809°; and if the heat be much increased, it is volatilized in white fumes. This white oxide of antimony was formerly called *argentine snow*, or *flowers of antimony*.

If antimony be brought to a white heat, and then shaken, it takes fire with a kind of explosion. If fused on charcoal before the blowpipe, and thrown into the air, it divides into globules, and burns with a brilliant white light as it falls to the ground.

The antimony of commerce is found in two states, that of crude antimony, and in the metallic state: crude antimony is the sulphuret of this metal; and is the only ore of it which is obtained in sufficient plenty to be wrought. Metallic antimony, better known by the name of *regulus*, is crude antimony deprived of its sulphur. If iron filings be fused with crude antimony, they combine with its sulphur, and the antimony is obtained pure. One-fifth of iron will combine with all the sulphur by which this metal is mineralized. In the large way, antimony is obtained by melting calcined antimony with dried wine lees in a reverberatory furnace, and the sulphur is often not wholly removed from it. Sulphuret of antimony contains 26 parts in the 100 of the metal.

Antimony will enter into combination with most of the metals. With platina it affords a brittle alloy, which is much lighter than platina. The platina cannot afterwards be separated from it by heat.

Gold may be combined with antimony by fusing them together, and the antimony may be separated by an intense heat.

Silver and antimony form a brittle alloy, the specific gravity of which is greater than intermediate between the specific gravities of the two metals.

Mercury does not combine freely with antimony. Gellert succeeded by using hot mercury, and covering the whole with water.

Equal parts of lead and antimony, form a porous and brittle alloy; three parts of lead and one of antimony is the best composition for printing types; and of all the alloys of antimony

it is the most useful. It forms a hard alloy, scarcely malleable, but so brittle as to break without bending, unless in very slender pieces; when properly prepared, its fracture has the appearance of that of cast steel. In fusing the two metals, the antimony should be well mixed by stirring, as from its levity it will float on the lead; if the mixture has not been complete, the alloy breaks with brilliant facets. This alloy is more fusible and fluid than either of the metals separately, and as antimony expands in cooling, it takes a sharp impression of a mould. Bismuth is sometimes added to increase this property, as well as the fusibility; but this metal is too costly to be added in any useful proportion, except for the smallest types. The antimony should be completely freed from sulphur, otherwise the types made of it undergo a spontaneous decomposition, easily break, and are covered with a black crust.

Twelve parts of lead and one of antimony, form an alloy very malleable, yet much harder than lead; 16 parts of lead and 1 of antimony, form an alloy which does not differ from lead, except in being rather harder.

Copper combines readily with antimony; the colour of the alloy is a beautiful violet, and its specific gravity is greater than intermediate.

The alloy formed by iron and antimony is brittle and hard; its specific gravity is less than intermediate. The disposition of iron to receive magnetism, is much impaired by antimony.

The alloy of tin and antimony is harder than tin, white, and brittle; the specific gravity of the alloy is less than intermediate, yet the combination is so intimate, that it is scarcely possible to separate the antimony from the tin. A small portion of antimony is added with tin to form pewter.

Le Sage analyzed some nails intended for ship-building, and found them to consist of three parts tin, two of lead, and one of antimony. These nails could be made to penetrate oak-boards, and were not acted upon by sea-water.

The alloy of zinc and antimony is brittle.

Pure water has some action upon antimony, for it becomes purgative by standing in a vessel made of this metal.

Sulphuric acid, boiled upon antimony, is slowly decomposed. Sulphurous gas escapes, and sulphur itself by continuing the process. The sulphate of antimony is deliquescent, and decomposed by the fire.

The nitric acid is decomposed by antimony very readily; a considerable part of the antimony is oxidized, and part of the oxide is dissolved. This oxide is very white, and difficult of reduction.

The muriatic acid acts feebly upon antimony, except by long digestion. The muriate of antimony, obtained by evaporation, is very deliquescent; it is fusible in the fire, and volatile.

Two parts of corrosive muriate of mercury, and one of the muriate of antimony, distilled by a gentle heat, afford the common *butter of antimony*, or sublimed muriate of antimony. This preparation is fluid at a gentle heat; by plunging the vessel which contains it into hot water, it becomes sufficiently fluid to pour out.

When butter of antimony is dropped into water, part of the metal, in the form of an oxide, is thrown down in a white powder. This substance is called *powder of algaroth*, which acts as a strong purgative.

If sulphuret of antimony be melted, and the heat continued, the sulphur sublimes, and the antimony is converted into a gray oxide; this oxide may likewise be obtained by powdering metallic antimony, and then submitting it to calcination. The oxide will combine with $\frac{1}{100}$ of sulphur, and this compound forms by fusion, a glass, called the *glass of antimony*.

Antimony supplies medicine with some of the most active and valuable remedies. The acid of tartar forms with it the preparation called *emetic tartar*, the new name of which is *antimoniated tartrate of potass;* it is composed of 56 parts tartrate of antimony, 36 tartrate of potass, and eight of water.

The alkalies and lime decompose the antimoniated tartrate of potass.

The alkalies alone have no perceptible action on antimony, but the alkaline sulphurets dissolve it completely. Kermes' mineral, a medicine formerly of great celebrity, is a red sulphuretted oxide of antimony. It is prepared by boiling together half a pound of the sulphuret of antimony in powder, and two pounds of potass, in eight pints of pure water, for fifteen minutes; stirring the mixture with an iron spatula; and then expeditiously filtering it whilst it is hot. The liquor is now suffered to stand in a cool place, where it soon deposits a powder that must be repeatedly washed, first with cold, and afterwards with hot water, till deprived of taste. The antimony may be used again, until entirely consumed. According to the quantity which is taken, Kermes' mineral operates as an emetic, purgative, sudorific, or expectorant; its active properties render half a grain in most cases sufficient at a time.

Phosphorus, thrown in small pieces upon melted antimony, combines with it. The phosphuret of antimony is of a white colour, brittle, and appears laminated when broken.

Tellurium.

Tellurium is a recently discovered metal, nearly white like tin, but verging a little to the grayness of lead. Its fracture is laminated. It is extremely brittle, and nearly as fusible as lead. When heated with the blowpipe upon charcoal, it burns with a very lively flame, of a blue colour, inclining at the edges to green. It is so volatile as to rise entirely in a whitish gray smoke, and exhales an odour like that of radishes. The smoke condenses into a white oxide. Its specific gravity is 6.115.

Klaproth, who discovered this metal, found it in an ore called the auriferous ore, otherwise *aurum paradoxicum*, which is obtained in Transylvania, and which contains but a very small quantity of gold.

Tellurium amalgamates with mercury by trituration. It is oxidized and dissolved in the principal acids. To sulphuric acid it gives a deep purple colour, and if this acid has been diluted with two or three parts of water, and a little nitric acid added, a considerable portion of tellurium will dissolve in it, and the solution will not be decomposed by water. The solution in sulphuric acid alone is separated by water in black flakes, and heat throws down a white precipitate.

With nitric acid, tellurium forms a colourless solution, which remains so when diluted, and affords slender, dendritic crystals by evaporation.

Tellurium dissolves in nitro-muriatic acid; the solution is transparent, and the addition of water precipitates a white powder, which is soluble in the muriatic acid. Alcohol produces a similar precipitate.

Iron, tin, zinc, and antimony, precipitate tellurium from its acid solutions in a metallic state, under the form of small black flakes, which resume their splendour by friction, and which on burning charcoal rapidly melt into a metallic button.

The alkalies throw down from the solutions of tellurium, a white precipitate, which is soluble in all the acids by an excess of the alkalies or their carbonates.

Tungsten.

Tungsten is externally of a brown colour, internally of a steel gray. Its specific gravity is 17.600, and it is extremely difficult of fusion.

This metal is in Sweden obtained from an ore in which its oxide exists in combination with lime; in Germany and England, it may be obtained from a mineral called wolfram,

in which it exists in combination with iron. The oxide of tungsten has acid properties, and it is therefore called the *tungstic acid.*

D'Elhuyart found that wolfram contained $\frac{65}{100}$ of tungstic acid; the rest of it consisted of iron, manganese, and tin. This acid substance being mixed with charcoal powder, was violently heated in a crucible. On opening the crucible after it had cooled, a button of metal was found of a dark brown colour, which crumbled to pieces between the fingers. On viewing it with a glass, it was found to consist of a congeries of metallic globules, some of which were as large as a pin head. These globules were the tungsten; the charcoal had combined with the oxygen of the acid substance, and left the metal pure. When heat is applied with access of air, tungsten is converted into a yellow powder, composed of 80 parts of tungsten, and 20 of oxygen. This is the *yellow oxide of tungsten*, or the *tungstic acid.*

Vanquelin considers that the substance formed by the combination of tungsten with oxygen, does not possess the properties generally attributed to acids; since it is insoluble in water, does not change the blue vegetable colours, and has no apparent savour. He advises it therefore to be called merely an oxide of tungsten, observing that Scheele, who regarded it as an acid, never obtained it but in a triple combination, which possesses acid properties.

Morveau asserts, that the oxide of tungsten renders vegetable colours so fixed, as not to be acted upon by the oxymuriatic acid.

Neither the sulphuric, the nitric, nor the muriatic acid, dissolves either tungsten or its oxide.

The alloys of tungsten, and the uses to which the metal itself may be applied, appear to be little known.

Solutions of caustic potass, soda, and ammonia, dissolve the oxide of tungsten, even in the cold, forming tungstate of potass, soda, and ammoniac.

Tungsten refuses to unite with sulphur.

A tungstate of magnesia is formed, by mixing oxide of tungsten with carbonate of magnesia and water; boiling the mixture, and straining it. An acid will precipitate a white powder, and by evaporation a soluble salt is obtained, which crystallizes in little bright spangles, and is unchangeable in air.

Rhodium.

Rhodium is one of the new metals obtained from the grains of crude platina. Its specific gravity is about 11. It is not malleable, and has never been perfectly fused alone. Sulphur and arsenic render it fusible, and may afterwards be expelled by heat.

Rhodium unites readily with every metal which Dr. Wollaston, its discoverer, tried, except mercury. With gold or silver the alloy is malleable, not oxidized by a high degree of heat, but becoming encrusted with a black oxide when slowly cooled. One-sixth of it does not perceptibly alter the colour of gold, but renders it much less fusible. Neither the nitric nor nitro-muriatic acid acts on it in the state of alloy with gold or silver, but if it be fused with three parts of bismuth, lead, or copper, the alloy is entirely soluble in a mixture of nitric with two parts of muriatic acid.

Uranium.

Uranium is of a dark gray colour on the surface; within it is of a pale brown. Its hardness is about 6; it is more difficult of fusion than manganese. It is little known, and appears not to have been obtained in a state of purity, as the specimens of different chemists have varied in specific gravity from 6.440 to 9.000.

Klaproth discovered uranium in a mineral called *pech-blende*, which is obtained in Saxony, and which had been usually considered as an ore of zinc or iron, or even tungsten; but Klaproth's analysis evinced that it was the sulphuret of uranium.

When exposed for some time to a red heat, in a close vessel, uranium suffers no change; but by means of nitric acid, it is converted into a yellow oxide. This oxide is soluble in diluted sulphuric acid gently heated, and affords prismatic crystals of a lemon colour. It is also soluble in nitro-muriatic acid, and may be precipitated by alkalies.

Uranium has not been applied to the arts.

Cobalt.

Cobalt is of a whitish colour, inclining to a bluish or steel gray. When pure, it is somewhat malleable while red-hot, and is also attracted by the magnet. Its hardness is 8, and its specific gravity is usually about 7.811. It is brittle, and has a dull, close-grained fracture. It is not acted upon by water, but tarnishes in the air; it requires, for its fusion, a heat not

inferior to that required for cast-iron. It has never been volatilized.

Cobalt has never been found native; but mostly in the state of an oxide, united with arsenic, sulphur, iron, &c. It is plentiful in the mines of Saxony; and is also abundantly obtained in this country in the Mendip Hills, Somersetshire, and in a mine near Penzance, in Cornwall.

Arsenical cobalt is of a gray colour, and becomes black by exposure to air. The sulphurous ore of cobalt resembles the gray silver ore in its texture.

When the oxide of cobalt has been freed from arsenic and sulphur, which is done by pulverizing it, washing it, and then exposing it to a strong heat, it has an obscure gray colour, and is called *zaffre*. When zaffre is fused with three parts of pulverized flints, and one of potass, a beautiful blue glass is obtained. This glass, when pulverized and washed, constitutes the *smalt* of commerce. Smalt is used to give the blue colour to writing papers, to starch, and linen. It also supplies a blue colour to the painters of earthenware and porcelain, and to enamellers.

Metallic cobalt may be obtained by fusing zaffre in a white heat, with three times its weight of black flux: the cobalt, when reduced, sinks to the bottom of the crucible. Or it may be obtained by fusing smalt with six or eight times its weight of soda.

Cobalt resists cupellation, nor will it amalgamate with mercury. It forms alloys with few of the metals; that with tin is of a light violet colour: the metals with which it combines most readily are arsenic and iron; these, when combined with it, are separated with difficulty. With iron the alloy is hard, and not easily broken; with arsenic it is brittle, fusible, and more easily oxidized than pure cobalt.

To dissolve cobalt in sulphuric acid, the acid must be highly concentrated, and distilled upon it almost to dryness. By washing the residuum, a portion of it dissolves in the water; this portion is sulphate of cobalt. The other part consists of oxide of cobalt. The cobalt may be precipitated from the water by lime and alkalies.

Nitric acid dissolves cobalt by the assistance of a gentle heat. Lime and alkalies precipitate it from its solution, and an excess of alkali dissolves the precipitate.

Muriatic acid does not dissolve cobalt without the assistance of heat. The nitro-muriatic acid dissolves cobalt more readily. This solution, much diluted, forms the much admired sympathetic ink, which when written with upon paper is invisible, but when the paper is warmed, the characters appear of a

beautiful green, that gradually disappears as the paper cools, and the experiment may be repeated with the same result for an indefinite number of times.

Sulphur is not readily combined with cobalt by art; but alkaline sulphurets readily form the combination.

The phosphuret of cobalt may be formed by dropping small pieces of phosphorus upon ignited cobalt in grains. It is white and brittle, and soon loses its lustre by exposure to the air: it is more fusible than cobalt.

Molybdenum.

The ore containing molybdenum has almost the appearance of plumbago, and therefore, though scaly and more shining, it was, before it was carefully analyzed, mistaken for that mineral. It is unctuous to the touch, soils the fingers, and makes whitish and brilliant traces upon paper, whereas the traces of plumbago are dull. It has never been perfectly reduced; when made into a paste with linseed-oil, or any other suitable substance, the strongest fires only agglutinate it in brittle masses consisting of small grains. These grains are of a whitish yellow colour, but their fracture is a whitish gray. Their specific gravity is at least 7.500.

The alloys of molybdenum have been little examined; those with silver, iron, and copper, are friable; those with lead and tin pulverulent and infusible.

Molybdenum, by a strong heat, is gradually converted into a whitish-coloured oxide. Nitric acid, which has a rapid action upon it, converts it into a *white oxide*. This oxide has the properties of an acid, and is therefore called *molybdic acid*. It dissolves in 576 parts of water at a mean temperature. It decomposes the solutions of soap, and precipitates alkaline sulphurets.

The muriatic acid has no action upon molybdenum, but dissolves its acid, which is also done by the sulphuric. Heat should be employed with both these acids.

Scheele discovered, 1, that fixed alkali rendered molybdic acid more soluble in water; 2, that this salt prevents the acid of molybdenum from volatilization by heat; 3, that molybdate of potass falls down by cooling, in small crystalline grains, and that it may likewise be separated from this solvent by the sulphuric and muriatic acids.

Blue carmine is prepared by precipitating tin from its solution in muriatic acid with the molybdate of potass. The muriatic acid unites with the alkali, and the molybdic with the tin, to form the blue precipitate.

Manganese.

A mineral, called the *soap of glass*, has been employed for time immemorial in the manufacture of glass, which it whitens and renders colourless. It is usually of a gray or blackish colour, and soils the fingers. This mineral is the oxide of a peculiar metal called *manganese*.

Metallic manganese is of a grayish white colour, brittle, though not easily broken, and devoid of malleability. When reduced to powder, it is attracted by the magnet. Its specific gravity is 6.990; its hardness 8. It is more difficult of fusion than iron.

When manganese is exposed to the atmosphere, it soon tarnishes, and becomes at last black and friable; heat accelerates this change, which produces the substance called the *black oxide of manganese*. It is this oxide of the metal which is usually employed in the arts, and in which state manganese is generally found. The counties of Somerset and Devon supply large quantities of it, and in the vicinity of Aberdeen a mine of it has been lately discovered, which furnishes twenty tons per week.

The black oxide of manganese contains 25 per cent. of oxygen; a portion of this oxygen is separated by heat, and therefore the oxide has recently become important, for the purpose of furnishing this gas. When manganese is employed in preparing oxymuriatic acid for medicine, the purest, such as that from Upton Pyne, should be used. That from Bristol and the Mendip Hills, generally contains lead.

Manganese is susceptible of three different degrees of oxydizement, forming the white, the red, and the black oxides of manganese. An oxide containing still more oxygen is asserted to be of a dark green.

Metallic manganese may be obtained, by mixing the black oxide into a ball with linseed-oil; putting this ball into a cavity made in a lump of charcoal, covering it with a layer of charcoal, enclosing the whole in a crucible, and subjecting it to an intense heat for one or two hours. Saline fluxes should be rejected for reducing this mineral, because it has so strong a disposition to vitrify, that it would be suspended in a flux of that kind.

Manganese unites by fusion with all the metals except mercury. With copper and iron it appears to combine the most readily; but none of its alloys are used in the arts, or known to be valuable.

The sulphuric acid attacks manganese, and produces hydrogen gas; the solution goes on more slowly than that of iron in the same acid; it is colourless. Sulphuric acid extricates from the oxide of manganese, a large quantity of oxygen gas.

The oxide of manganese is dissolved by nitric acid; and muriatic acid, digested upon it, seizes its oxygen, and passes in vapour through the water. This vapour is oxymuriatic acid.

The oxide of manganese combines with alkalies. It also combines with sulphur, which the metal does not.

Manganese at a red heat, combines with phosphorus. The phosphuret is of a white colour, brittle, granulated, disposed to crystallize, not altered by exposure to the air, and more fusible than manganese.

Tantalium.

From a fossil called *tantalite*, and another called *ytrotantalite*, Ekeberg extracted by means of the fixed alkalies, a white powder, which he ascertained to be the oxide of a peculiar metal. To this metal he gave the name of *tantalium*.

When the oxide of tantalium above mentioned is powerfully heated with charcoal, a button of metal is obtained, with a metallic lustre externally, but internally black and without brilliancy. Its hardness is 7; its specific gravity 6.5. The acids will reduce it again to the state of white oxide, but they will not dissolve it. The oxide is not changed by a red heat. Caustic fixed alkali is the only re-agent which has any action upon it.

Titanium.

Titanium is of a brownish red colour, almost like copper. Its lustre is considerable, it is brittle, and very difficult of fusion. Its specific gravity is 4.18; its hardness 9.

Titanium is obtained from a mineral, plentiful in Hungary, called *red schorl*, which is its native red oxide; and from another mineral obtained in Cornwall, called *menachanite*.

Vauquelin obtained metallic titanium from its native red oxide, by mixing together 100 parts of this oxide with 50 of calcined borax, and 50 of charcoal, formed into a paste with oil; and exposed the whole to the heat of a forge raised to 166° of Wedgwood.

This metal is acted upon by the principal acids, except the nitric, and forms salts with them. It also combines with

phosphorus. The phosphuret is of a pale white colour, brittle, granular, and infusible by the blowpipe.

The attempts to alloy titanium have not succeeded.

Chromium.

Chromium is of a whitish colour, inclining to gray; it is very brittle; its fracture presents a radiated appearance, needles crossing in different directions, with interstices between them. It is difficult of fusion, resisting the heat of the blowpipe.

Chromium was discovered by Vanquelin, in analyzing a beautiful mineral called *red lead of Siberia*. The mineral is a chromate of lead, in which chromium exists in the state of an acid. Its colour is a fine aurora red, with considerable lustre. Chromium has also been found united with iron, forming chromate of iron; it also exists in some gems, of which it appears to constitute the colouring principle. In the emerald it exists in the state of green oxide, and the spiral ruby contains it in the state of an acid.

Vanquelin extracted this metal from the red-lead ore, by adding to it muriatic acid, which combines with the oxide of lead, and forms a compound that is precipitated, the chromic acid remaining in solution. To abstract a little muriatic acid combined with it, oxide of silver is cautiously added, and the pure chromic acid being decanted from the precipitate of muriate of silver, and evaporated, is exposed to a very strong heat excited by a forge, in a crucible of charcoal, placed within another of porcelain. It is thus reduced to the metallic state.

Sulphuric acid decomposes the red-lead ore, but it is difficult to separate the products. Nitric acid does not decompose this ore.

Chromic acid is very soluble in water; it is of an orange-red colour, with a pungent metallic taste; by evaporation, it affords crystals in long slender prisms of a ruby red colour. This acid combines with the alkalies, earths, and metallic oxides, and the neutral salts which it forms with them are called *chromates*.

The combinations of this acid with metallic oxides are in general possessed of very beautiful colours, and are well adapted to the purposes of painting. That with oxide of lead has an orange yellow, of various shades; that with mercury, a vermilion red; with silver, a carmine red; with zinc and bismuth, the colours are yellow; with copper, cobalt, and antimony, they are dull.

The term chromium is derived from a Greek word signifying colour, and is applied to this metal on account of the diversity of colours which its compounds form.

The specific gravity of chromium and the four following metals is uncertain.

Columbium.

A mineral in the British Museum, sent to Sir Hans Sloane with some iron from Massachusets, upon being examined by Hatchett, was found to contain a new metallic substance, to which that eminent chemist has given the name of *columbium.*

The ore of columbium has never been perfectly reduced, but it affords an acid, called the columbic acid, which differs from all other bodies. The alkalies throw it down from its acid solutions, in white flakes. Prussiate of potass changes the colour to an olive green, and a precipitate of the same colour is gradually formed. Tincture of galls produces a deep orange-coloured precipitate. Zinc occasions a white precipitate. The fixed alkalies readily combine with the columbic acid. It is insoluble and unalterable with regard to colour by the nitric acid.

Cerium.

Cerium is another newly discovered metal, which exists in a mineral called *cerite.* Cerite is semi-transparent, generally of a reddish colour, though occasionally yellowish. Some specimens are hard enough to scratch glass, and to strike fire with steel. To obtain the oxide of cerium, this mineral is pulverized, calcined, and dissolved in nitro-muriatic acid. The filtered solution, being neutralized with potass, is to be precipitated by tartrate of potass; and the precipitate, well washed and afterwards calcined, is oxide of cerium. This oxide is susceptible of two degrees of oxidation; in the first it is white, and this by calcination becomes of a fallow red.

The white oxide of cerium, mixed with a large proportion of borax, fuses into a transparent globule; but in attempts to obtain the metallic cerium, the quantity operated upon has always been so far dissipated, that the sensible properties of the metal are unknown.

Iridium.

In a black powder left after dissolving crude platina, Tennant discovered two new metals, to one of which he gave the name of *iridium.* To analyze this powder, it was mixed

with pure dry soda, and kept at a red heat for some time in a silver crucible. The alkali was then separated by solution in water, and the undissolved part of the powder was digested with muriatic acid, with which a solution at first of a dark blue was obtained; it afterwards became of a dusky olive green, and at last of a deep red. This acid solution contains two metals, but chiefly iridium. By its evaporation may be obtained an imperfectly crystallized mass, which, dissolved in water, gives by evaporation distinct octahedral crystals. These crystals, dissolved in water, produce a deep red solution, inclining to orange. By exposure to heat, the acid may be expelled, but the iridium thus obtained has never been fused except by a powerful galvanic battery. Its oxide, when obtained as above stated, is white; it neither combines with sulphur nor arsenic. Lead unites with it easily, but is separated by cupellation, leaving the iridium on the cupel, in the form of a coarse black powder. Copper and silver form with it malleable alloys; but the iridium appears to be diffused through the silver only in the state of a fine powder. Gold remains malleable, although alloyed with a considerable portion of it; and is not separated from it either by cupellation or quartation.

Osmium.

The metal found along with iridium, in the black powder left after dissolving platina, is called *osmium*.

The oxide of osmium may be obtained by distilling with nitre the black powder above mentioned; at a low red heat, an apparently oily fluid sublimes into the neck of the retort, which, on cooling, concretes into a solid, colourless, semi-transparent mass. This being dissolved in water, forms a concentrated solution of oxide of osmium. This solution indelibly stains the skin of a deep red or black. Infusion of galls renders the solution at first purple, but in a little time it becomes of a deep vivid blue. If mercury be agitated with the solution, it forms with the osmium a perfect amalgam; part of the mercury may be separated by squeezing it through leather, and the rest by distillation, which will leave the osmium pure, in the state of a black powder. This powder has never been fused. It forms malleable alloys with copper and gold.

OF COMPOUND SUBSTANCES.

Alkalies.

Alkalies are possessed of the following properties:

1. They are soluble in water; 2, they have an acrid and urinous taste; 3, they are incombustible; 4, they change most vegetable blues to green, and the yellow to a brown; 5, they form neutral salts with acids; 6, they render oils miscible with water.

The alkalies are three in number, *potass*, *soda*, and *ammonia*. Potass and soda are called *fixed* alkalies, because they are not volatilized, except by an intense heat; ammonia is called the *volatile* alkali, because it is dissipated or converted into gas at a moderate heat.

Oxygen is a component part of all the alkalies, and appears clearly, in the case of the two fixed alkalies at least, to be the alkalizing principle. The bases of the alkalies are metals; of two of them, called potassium and sodium, we have already treated; that from ammonia has been very little examined.

Potass.

If the ashes of burnt vegetables be repeatedly lixiviated, until they cease to communicate any taste to the water, and the water be evaporated to dryness, a saline residue is obtained, which in commerce is known by the name of *potash*. It has been called the *vegetable alkali*, because it was supposed to be furnished by vegetables only.

Potash contains a number of foreign salts, and other impurities; but when deprived of all these, it is called by chemists *potass*.

Pure potass is extremely white, and so caustic, that if applied to the hand, the skin is instantly destroyed; it is therefore in this state called *caustic alkali*.

The potash of commerce is always combined with carbonic acid, for which it has a strong affinity, and it is this addition which disguises its properties more than all the rest, and reduces it to its usual state of what is called *mild* alkali, or by chemists *carbonate of potass*, or rather *sub-carbonate of potass*, as it is not saturated with the carbonic acid.

If potash be dissolved in water, and mixed with an equal quantity of quicklime made into a paste with the same fluid,

the lime having a greater affinity for the carbonic acid than the potass, will combine with it; the potass remains in solution, and may be separated from the lime by filtration. The evaporation of this solution should be performed in close vessels, otherwise the potass will abstract carbonic acid from the air.

Potass is soluble in its weight of water; it attracts moisture from the gases with great avidity, and therefore affords the means of drying them. It is soluble also in alcohol, which is not the case when it is in the state of a carbonate.

By exposure to heat, potass becomes soft, and at the commencement of ignition it melts into a transparent glass; by increasing the heat it is volatilized.

Potass and silex, when fused together in equal quantities, combine and form *glass*. If the proportion of potass to that of silex be as three or four to one, the glass will be soft, and soluble in water; this composition is called *siliceous potass*, or *liquor of flints*.

If a solution of potass be boiled upon silex recently procured, it dissolves a part of it. As the solution cools, it assumes the appearance of a jelly, even though previously diluted with seventeen times its weight of water.

Potass combined with fixed oils, forms soap.

It combines with sulphur both in the dry and the humid way, forming *sulphuret of potass*. When this sulphuret is obtained by the fusion of its component parts, it is of a brown colour, soluble in water, and soon attracts water from the atmosphere. When it has acquired moisture, it is then in a state to act on the air, from which it will abstract oxygen, and if inclosed with a quantity of it in a jar, the nitrogen will be left alone.

Sulphuret of potass, allowed to remain moist in the atmosphere, is at length converted into sulphate of potass; for the sulphur, combining with oxygen, forms sulphuric acid, and the water is decomposed, giving out sulphuretted hydrogen gas.

Soda.

Soda called also *mineral* or *fossil alkali*, because it was considered as exclusively derived from the mineral kingdom, is nearly similar to potass in its properties.

Soda is one of the most abundant substances, but it is never met with naturally, except in a state of combination. It forms common salt when combined with muriatic acid, and this compound is therefore called *muriate of soda*. Hence those inexhaustible mines of salt, which are found in England,

Poland, and other countries, and even the ocean itself, which holds it in solution, are so many vast depositories of soda.

The French chemists have attempted to obtain muriatic acid and soda, by the decomposition of sea-salt, but the process is too expensive for general use. The soda of commerce is therefore obtained from the ashes of marine plants, and from one of these (the *salsola soda*) it derives its name. In Scotland this and other sea-weeds are collected, dried, and burned in pits dug in the sand, or in heaps surrounded by loose stones. Fresh quantities are added, as the first are consumed, and a hard residuum is obtained, which is of a black or bluish colour; it is called *kelp*, and contains from 2½ to 5 per cent. of soda. On the coasts of France and Spain, the same kind of manufacture is carried on, and the produce is called *barilla*. The barilla of Alicant is much noted.

Soda is obtained from kelp and barilla by lixiviation, filtration, and crystallization. These processes leave it in the state of a carbonate, but it may be deprived of its carbonic acid, and rendered caustic, by lime, in the same manner as potass.

Potass and soda, in a state of purity, cannot be distinguished by inspection from each other. The oxalic acid has been used as a test to distinguish them. This acid, with potass, forms a very soluble salt, but with soda, one of difficult solubility. A solution of the ore of platina in nitro-muriatic acid also affords the means of distinguishing them; for the solution of potass will form a yellow precipitate, but soda gives no precipitate.

Fourcroy suggests that soda is the most proper of the two fixed alkalies to be employed in medicine; because animal substances always contain it, but they never contain potass.

If potass be exposed to the atmosphere, it deliquesces, that is, acquires moisture; if soda be exposed in the same manner, it effloresces, that is, parts with moisture, and is converted into a dry powder.

Soda is preferred to potass in most manufactures, its affinities in general are not so strong as those of potass, it is therefore less corrosive. It is more fusible alone, and fuses silex more readily than potass, hence it is employed in the manufacture of glass.

Carbonic acid renders soda, as well as potass, fit for many purposes to which, in its caustic state, it would not be applicable. It is in this state that these alkalies are employed in medicine, and in washing linen.

The combination of potass or soda with oil or tallow, forms soap; but soda forms hard soap, while potass only affords soft soap. Soda is therefore much more valuable, and generally used in the manufacture of soap, for which use it is ren-

dered caustic by quicklime. Muriate of soda is added in making soap, in order to harden it. The brown or yellow soap contains a quantity of rosin. Black or green soft soap is made with the coarsest oils, and retains all its alkaline ley.

The weakest acids have the power of decomposing soap, because they have a stronger attraction for its alkali than the oil. Soap is also decomposed by metallic oxides, earths, and neutral salts. Hence the water of springs is said to be *hard*, because soap is not soluble in it, or rather is not decomposed by it. Solution of soap may therefore be employed to shew whether water holds minerals in solution or not.

Ammonia.

If muriate of ammonia, in powder, be mixed with three parts of slacked lime, and distilled, and the product be collected by the mercurial trough, or pneumatic apparatus, a gas is obtained, which is transparent and colourless, like common air. This gas is called *ammoniacal gas*, and is the purest state in which ammonia can be exhibited.

Ammonia has a pungent, though not unpleasant smell. Its taste is acrid and caustic, like that of the fixed alkalies, but not so strong; nor has it the property, like them, of corroding animal substances. It is not respirable. Its specific gravity is to common air as 3 to 5. When exposed to a cold of 45°, it is condensed into a liquid, which again assumes the gaseous form, when the temperature is raised.

Ammonia is rapidly absorbed by water, and the absorption goes on till the water has acquired above a third of its weight of it. It therefore instantly disappears if water be introduced into a jar of it; some caloric is evolved, and the specific gravity of the water is diminished. If ice be introduced into this gas, it melts and absorbs the ammonia, while at the same time its temperature is diminished. The specific gravity of water saturated with ammonia, at 60° is .9054. It is the attraction of water for ammonia, which renders it necessary to employ mercury in obtaining the gas.

Water combined with ammonia, acquires its smell, and has a disagreeable taste; it converts vegetable blues to green. It is this liquid solution of ammonia which is meant in speaking of the volatile alkali. When heated to the temperature of 130°, the ammonia separates in the form of gas. When its temperature is reduced to —46°, it crystallizes; and when suddenly cooled down to 68°, it assumes the appearance of a thick jelly, and has scarcely any smell.

Ammonia may be obtained by the dry distillation of bones and other animal matters; it is from such substances that it is obtained to supply the demand of commerce, and it is sold under the name of *spirits of hartshorn*. The product of the first distillation from bones, &c. is very impure; it is therefore improved by repeated distillations.

Berthollet's experiments evinced that one thousand parts of ammonia consists of 807 parts of nitrogen, and 193 parts of hydrogen; but Sir H. Davy having discovered oxygen to be the alkalizing principle in potass and soda, was convinced of the probability of its existing in ammonia. His researches confirmed this opinion, and he concludes the proportion of oxygen in ammonia to be at least 7 or 8 per cent. He also succeeded in separating from it a substance of a metallic nature. The ammonia was decomposed by galvanism in contact with mercury. The mercury, by combining with about one twelve-thousandth part of this new matter, has its identity destroyed; it becomes solid, and its specific gravity is reduced from 13.5 to less than 3.0, but its colour, lustre, opacity, and conducting powers, remain. The difficulty of obtaining and operating upon this substance, has hitherto prevented its being sufficiently known to assign its proper place in the classification of bodies.

Ammoniacal gas has no effect upon sulphur or phosphorus. Charcoal absorbs it, without altering its properties when cold; but when the gas is made to pass through red-hot charcoal, part of the charcoal combines with it, and forms *prussic acid*.

The two gaseous substances, ammonia and muriatic acid, combine rapidly, and form the solid substance called *muriate of ammonia*, which is the *sal ammoniac* of commerce. This is one of the most remarkable and curious facts: separately, ammonia and muriatic acid gas are two of the most pungent and volatile substances known; in union, they are hard, inodorous, not volatile, and possess but little taste.

Muriate of ammonia was formerly supplied by Egypt: but it is now made in this country from soot.

Ammonia combines with oils, and forms soap; it does not combine with the metals, but it changes some of them into oxides, and then dissolves them. Liquid ammonia is capable of dissolving the oxides of silver, copper, iron, tin, nickel, zinc, bismuth, and cobalt. Its use in medicine is considerable; it has given relief in cases of apoplexy.

Of Acids.

Acids possess most or all of the following properties: 1. They excite the sensation called *sourness*, or *acidity*; 2. They change the blue, green, and purple juices of vegetables to red; 3. They combine with alkalies, earths, and metallic oxides, with which they form the compounds called *salts*. 4. They combine with water in all proportions.

Most of the acids have been proved to contain oxygen as a component part; and are more or less strong in proportion as they are combined with more or less oxygen. They are not all, however, capable of combining with more than one dose or proportion of oxygen; a few are capable of combining with two doses of oxygen, and a still smaller number with three; no acid has been obtained by itself in combination with a fourth proportion of oxygen. These differences, it becomes necessary to distinguish, and the distinction is made in the following manner.

When any body contains the smallest portion of oxygen which converts it into an acid, the name of the base or radical of the acid, is terminated by *ous*, thus we have the *sulphurous* acid: the next degree of oxygenizement is expressed by the termination *ic*, thus we say *sulphuric* acid: the third degree is expressed by the addition of the word *oxygenized*, or its contraction *oxy*; thus we have the *oxymuriatic* acid: a fourth degree of oxygenizement may be expressed by placing the term *hyper* before that of *oxy*; thus we have, *hyper-oxy-muriatic* acid. There is only one instance of this last mode of expression being necessary, and that instance only refers to the acid as it is supposed to exist in combination with another body.

The number of acids which have been discovered, amount to thirty-seven, and are usually classed according to the nature of the substances from which they are generally derived.

I.—*Mineral Acids.*

1. Sulphuric,
2. Sulphurous,
3. Nitric,
4. Nitrous,
5. Muriatic,
6. Oxy-muriatic,
7. Carbonic,
8. Fluoric,
9. Boracic,

II.—*Metallic Acids.*

1. Arsenic,
2. Arsenous,
3. Tungstic,
4. Molybdic,
5. Molybdenous,
6. Chromic,
7. Columbic.

III.—*Vegetable Acids.*

1. Acetic,
2. Acetous,
3. Malic,
4. Oxalic,
5. Citric,
6. Tartaric,
7. Benzoic,
8. Camphoric,
9. Gallic,
10. Succinic,
11. Suberic.

IV.—*Animal Acids.*

1. Phosphoric,
2. Phosphorous,
3. Bombic,
4. Sebacic,
5. Laccic.
6. Amniotic,
7. Lactic,
8. Mucous,
9. Uric,
10. Prussic.

This classification cannot be proposed as very scientific or accurate; but some of the acids are too little known to give it any substantial improvement; and it answers the purpose of distinction better than some other modes of classification, the acids being often referred to in general, as mineral, vegetable, &c.

Sulphuric Acid.

Sulphuric acid is the union of oxygen and sulphur, in which the proportion of sulphur is, according to Berthollet, 63.2, and that of oxygen 36.8.

That sulphuric acid is a product of combustion, is evinced by the experiment, (see page 346,) in which sulphur, set on fire, and plunged into pure oxygen, is converted into it. After sulphur has been thus burnt, if no water be present, the acid is in the state of a dense white vapour, resembling snow. If water be present, it attracts these vapours, and when properly concentrated, forms a liquid, which is the sulphuric acid of commerce.

Sulphuric acid is strongly corrosive, and destitute of colour and smell. It may be rendered twice the weight of water, but its customary specific gravity seldom exceeds 1.8. When concentrated only to 1.7, it will freeze sooner than water, but not if either more or less concentrated. This was discovered by Keir. Sulphuric acid is so intensely acidulous, that though

diluted with 7000 times its weight of water, its taste is still distinguishable.

Sulphuric acid was formerly procured by distillation from the salt which, previous to the adoption of the new nomenclature, was called *green vitriol;* on this account, and its having in some measure an oily consistence, it was called *oil of vitriol.* At present, it is furnished for the demand of trade, by burning sulphur in close chambers, with the addition of nitrate of potass, to supply oxygen. The floor of the chamber is covered by a leaden cistern, containing water, by which the vapours of the sulphur are attracted and condensed. This process does not furnish the acid in a state of purity; but at least communicates to it some of the foreign substances, lead and potass. It is purified by distillation.

Sulphuric acid speedily destroys the texture of animal and vegetable substances; it changes all vegetable blues to red, with the exception of indigo. It has a strong attraction for water, of which Neumann asserts it will abstract from the atmosphere 6.25 of its own weight.

When sulphuric acid is mixed with water, much caloric is evolved, and the specific gravity of the compound is greater than intermediate. The mixture of four pounds of the acid, with one pound of water, will raise the thermometer to 300°.

Sulphuric acid decomposes alcohol and oils; when assisted by heat, it decomposes most of the metallic oxides, and most readily those which contain the greatest quantity of oxygen, as the red oxide of lead, the black oxide of manganese.

It oxidizes iron, zinc, and manganese in the cold. Assisted by heat, it oxidizes silver, mercury, copper, antimony, bismuth, arsenic, tin, and tellurium. At a boiling heat, it oxidizes lead, cobalt, nickel, and molybdenum. It has no action upon gold, platina, tungsten, or titanium.

It unites readily with all the alkalies, and alkaline earths, also with alumine, and zircon; with which, and most of the metallic oxides, it forms salts, which are called *sulphates;* thus *sulphate of potass,* formerly called *vitriolated tartar,* is a combination of the sulphuric acid and potass; and *sulphate of soda,* (Glauber's salts,) is a combination of sulphuric acid and soda.

Sulphurous Acid.

If sulphuric acid be deprived of part of its oxygen, it is converted into *sulphurous* acid; but the quantity of oxygen which must be abstracted to effect this change, or, in other words, the quantity of oxygen which is contained in sulphurous acid, has never been ascertained.

Sulphurous acid is the result of a very slow combustion of sulphur, whereas, in a rapid combustion, the sulphur combines with more oxygen, and forms sulphuric acid.

It is usually procured by mixing with sulphuric acid, oil, grease, metals, or any other substance that has a stronger affinity for oxygen than sulphuric acid, and proceeding to distillation. Sugar is one of the best substances which can be employed. By this means the acid is obtained in a gaseous form, in which state it is colourless and invisible like common air, exhales the odour of burning sulphur, and cannot be breathed without suffocation. Extreme cold converts it into a liquid. When combined with water, for which it has a strong attraction, it does not entirely lose its smell, like sulphuric acid.

Blue vegetable colours are reddened by sulphurous acid, previous to their being discharged.

This acid does not oxidize so many of the metals as sulphuric acid. The metals upon which it has this effect, appear to be only iron, zinc, and manganese.

With the alkalies, alkaline earths, alumine, and some of the metallic oxides, it forms the salts called *sulphites*.

Nitric Acid.

Nitric acid is formed by the chemical union of about 25 parts by weight of nitrogen, with 75 parts of oxygen.

By mixing nitrogen and oxygen in these proportions, and passing a number of electrical shocks through the mixture, nitric acid is produced. In other words, the combustion of nitrogen produces nitric acid.

Nitric acid, combined with potass, forms the salt called *nitrate of potass*, or saltpetre, and it is by the decomposition of this salt, that it may be procured. If three parts of nitrate of potass, with one of sulphuric acid, be distilled, the nitric acid, mixed with a small proportion of the nitrous, comes over. The nitrous acid may be expelled by a gentle heat. Nitric acid is clear and colourless, like water; it corrodes animal substances, and stains the human skin a permanent yellow. Its smell is remarkably pungent, and its taste strongly acid: in short, it eminently possesses all the properties enumerated as peculiar to acids. The action of light alone will, however, separate a part of its oxygen, and cause it to assume a yellow colour.

Nitric acid has a strong affinity for water, and has never been obtained except in combination with it. When concentrated, it attracts moisture from the atmosphere, but not so powerfully as the sulphuric acid. When mixed with water, it

produces heat, but not in equal degree with the sulphuric acid. It boils at 248°. When concentrated to the utmost, its specific gravity is about 1.5. When diluted with water, it is sold under the name of *aquafortis*: even the double aquafortis of the shops is only about half the strength of nitric acid.

Nitric acid is easily decomposed, and it therefore constitutes a valuable agent to the chemist. It is capable of oxidizing all the metals, except gold and titanium, and even gold it appears to attack in a slight degree. If brought into contact with hydrogen at a light temperature, a violent detonation is produced. If mixed with oils, it sets them on fire, and both the acid and the oil is decomposed. The oils should be free from water, but as this is rarely the case, the experiment is most certain of success if a little sulphuric acid be mixed with the nitric acid, as that acid will combine with the water. Oils deprived of water by boiling, inflame with nitric acid alone. In making these mixtures, the operator should keep himself at a distance from them, by using vessels with long handles.

Perfectly dry charcoal is also inflamed by nitric acid; with dry filings of iron the same effect takes place; and also with zinc, bismuth, and tin, if the acid be poured upon them in fusion.

The nitric acid, with alkalies, alkaline earths, alumine, zircon, and the oxides of metals, forms the salts called *nitrates*.

Nitrous Acid.

According to the principles of the new nomenclature, there is no acid strictly entitled to the appellation of *nitrous acid*; the acid which obtains this name is not the acid of nitre with a minimum of oxygen, but nitric acid combined with different proportions of nitric oxide, of which an account will be found under the head of oxides.

Nitrous acid is more or less coloured, according to the quantity of nitric oxide with which it is impregnated. It parts with the gas very readily, which, when in quantity, passes off in vapours that assume a red colour on mixing with the atmosphere. On account of the extrication of these vapours, the acid is sometimes called fuming aquafortis. The addition of different portions of water causes nitrous acid to appear blue, green, yellow, &c. but the vapours are always of the same red hue.

The general properties of nitrous acid, are similar to those of the nitric: with different bases it forms the salts called *nitrates*: these are not formed by the direct union of their component parts, but by exposing nitrates to a high temperature, which separating a part of their oxygen, leaves them in the state of nitrates.

Muriatic Acid.

Muriatic acid, so generally known under the name of *spirit of salt, or marine acid*, is a combination of oxygen with an unknown base; for the acid has never been decomposed.

In its combinations it is very abundant in the mineral kingdom, particularly with soda, lime, and magnesia. Its combination with soda forms common salt, and the affinity of the two substances is such, that they are not separated by a heat which volatilizes salt. In obtaining this acid from muriate of soda, therefore, some substance must be used which will combine with the alkali. Sulphuric acid, or substances which contain it, such as clay, are generally used. Mix one part of sulphuric acid with two parts of dry muriate of soda, in a glass retort, apply a gentle heat, and use the mercurial pneumatic trough, to collect the product which comes over. The product is muriatic acid in the state of gas This gaseous acid is invisible and elastic, like common air, but has about twice its specific gravity. It has a pungent, suffocating smell, and is extremely caustic.

Muriatic acid gas absorbs water with avidity. Water will combine with its weight of the gas, and the specific gravity of the liquid muriatic acid thus obtained is 1.5: it is, however, not easily procured and preserved of a greater specific gravity than 1.196.

Liquid muriatic acid is generally of a pale yellow colour, but this colour is attributed to the presence of some impurity; it preserves the smell of the gas, is very volatile, and gives out white fumes by exposure to the atmosphere.

It is capable, by the assistance of heat, of oxidizing iron, tin, lead, zinc, bismuth, cobalt, nickel, manganese, antimony, and arsenic. At a boiling heat, it oxidizes silver and copper. On gold, platina, mercury, tungsten, molybdenum, tellurium, and titanium, it has no action.

The proper solvent for gold and platina, is the nitro-muriatic acid, composed of one part of muriatic, and two of nitric acid.

Muriatic acid is the best test for silver. A single drop of it poured into a solution containing this metal, will cause a copious precipitate.

Muriatic acid, combined with different bases, forms the salts called *muriates*.

This acid, in the state of gas, has a powerful effect in neutralising putrid effluvia. Morveau, by pouring two pounds of sulphuric acid upon six pounds of common salt, and leaving

the mixture on a chafing-dish of live coals, completely destroyed the putrid exhalations which had caused the cathedral of Dijon to be deserted.

Oxymuriatic Acid.

If 84 parts of muriatic acid be combined with 16 of oxygen, they form *oxymuriatic acid.* This combination is usually formed by adding to one part of the black oxide of manganese, two parts of strong muriatic acid, and distilling the mixture with a gentle heat. The gas obtained is received over water, by means of the pneumatic apparatus.

Oxymuriatic acid gas is tinged of a yellow colour by contact with atmospheric air; it supports flame, but cannot be breathed without producing the most injurious effects. Pelletier having attempted to respire it, the consequence was a consumption, which in a short time put a period to his life. If it happen to be accidentally inhaled, the vapour of volatile alkali, for which it has a strong affinity, is the best remedy. It does not readily unite with water; and at the temperature of freezing water, it crystallizes.

Other acids become more intensely sour by an additional dose of oxygen, but the muriatic has this property diminished by the same addition. The taste of oxymuriatic acid is harsh and styptic, and instead of reddening vegetable colours, it changes them all to white, and their colours cannot be restored either by acids or alkalies. On this account, it is extensively used in the process of bleaching. After having been thus employed, upon a sufficient quantity of materials, it is converted into common muriatic acid. It has therefore produced its effect by imparting oxygen.

As the oxymuriatic acid eradicates writing ink, but has no effect upon printing-ink, it may be conveniently used for whitening soiled books and prints; it removes all stains but those of an oily nature. An easy mode of preparing a small quantity of it, consists in adding one ounce of the red oxide of lead to three ounces of muriatic acid. The red lead supplies the oxygen which oxygenizes the acid. This preparation should not be made till near the time against which it is wanted, and when made it should be kept in the dark, as it is deoxygenized by the light.

The nitro-muriatic and oxymuriatic acids have the same appearance and odour, as well as the same effects, as solvents. It appears, therefore, that the nitric acid, when added to the muriatic, has only the effect of supplying it with oxygen.

Oxymuriatic acid oxidizes nearly all the metals without the assistance of heat. It decomposes the red sulphuret of mercury, which neither the sulphuric or nitric acid will accomplish.

It may be combined with a great number of bases; the salts which it forms detonate with carbon and several metallic substances.

Hyper-oxymuriate of potass is made by introducing the oxymuriatic acid gas into a solution of potass; its crystals, as well as those of the common muriate, being formed on evaporation in the dark. It gives a faint taste, with a sensation of coldness in the mouth; the crystals have somewhat of a silvery appearance, and emit light by attrition. It is decomposed by the action of light, parting with oxygen, and becoming simple muriate of potass. Heat also separates its oxygen in the form of gas; 100 grains of it will yield 75 cubic inches of oxygen gas.

When three parts of hyper-oxymuriate of potass, and one of sulphur, are triturated in a mortar, the mixture detonates violently. The same effect is produced when the mixture is struck with a hammer upon an anvil.

Phosphorus and hyper-oxymuriate of potass detonate with prodigious force.

Exotic seeds which could not be caused to germinate by ordinary means, have germinated after being steeped for a few days in weak oxymuriatic acid.

Carbonic Acid.

Carbonic acid gas is the result of the combustion of carbon. Every 100 parts of it, according to Tennant, contain 18 parts of carbon and 82 of oxygen. Its weight is to atmospheric air as 1500 to 1000. It has no smell; is invisible and elastic, like common air, but extinguishes flame, and is totally unfit for respiration.

Carbonic acid is contained in the atmosphere to the amount of about one part in the thousand. It is absorbed by water if agitated, or long in contact with it. Strong pressure will cause the water to absorb three times its bulk of this gas, which imparts to it a taste agreeably acidulous, and causes it to have a sparkling lustre when poured from one vessel to another. The Pyrmont, Spa, and Seltzer waters, which are imported from the Continent, are instances of the natural combination of carbonic acid with water, and they can be imitated by art with the greatest precision.

The specific gravity of water saturated with carbonic acid is

1.0015. If water containing carbonic acid be frozen, the whole of this gas separates in the act of freezing, and therefore ice is never found to contain any. A boiling heat also produces this separation.

Carbonic acid, from its gravity, may be poured from one vessel to another, but if a portion of it be left in an open vessel, for any length of time, it will be found to have escaped; the air having an attraction for it, gradually absorbs it, and will even abstract it from water.

Carbonic acid exists in incalculable quantities, combined with other substances. Marble, limestone, and chalk, consist of it in combination with lime; it forms about one-third of their weight, and may be disengaged from any of these substances, by means of an acid, or considerable heat. The former means is generally more convenient, when a quantity is required for the purpose of experiment. The sulphuric acid, diluted with about six times its weight of water, is poured upon the marble, chalk, or limestone, previously reduced to a powder. An effervescence immediately ensues; this is occasioned by the extrication of carbonic acid gas, which must be collected by means of the pneumatic apparatus. The mercurial trough should be used, if the gas is not intended for immediate use.

Alcohol and spirit of turpentine absorb double their weight of carbonic acid gas; olive oil its own bulk. Ether mixes with it in the state of gas.

Carbonic acid enters into combination with alkalies, alkaline earths, alumine, zircon, and metallic oxides, with which it forms salts called *carbonates*.

Water impregnated with carbonic acid, and applied to the roots of plants, is highly favourable to vegetation; but if this gas be applied to the leaves as an atmosphere, it is injurious.

Fluoric Acid.

This acid is contained in the mineral called *fluor* or *fusible spar*, which consists of fluoric acid and lime. If sulphuric acid be poured upon this spar in powder, the lime combines with it to form sulphate of lime, and the fluoric acid is expelled, and may be collected by the pneumatic apparatus. The sulphuric acid should be well concentrated, and equal in weight to the fluor spar. A leaden retort must be used in the distillation, and only a gentle heat will be required. The gas should be received over mercury.

Fluoric acid gas is invisible and elastic like common air; it will not maintain combustion, and cannot be breathed without

causing death. It has the odour of muriatic acid, but is more corrosive, and when exposed to a moist atmosphere, it becomes cloudy.

Fluoric acid gas is heavier than common air. It corrodes the skin almost instantly. It combines rapidly with water, with which it forms liquid fluoric acid; as it dissolves silex, it cannot be prepared in glass vessels, nor kept in them, unless they be lined internally with wax or some similar coating. The acid combines with the silex of glass, and the silex passes over with it, in the distillation. It is for this reason that it is usually kept as well as prepared in leaden or tin bottles.

It is absorbed by alcohol and ether without altering their qualities. Water impregnated with it must be cooled down to 23° before it will freeze.

The action of fluoric acid, upon all inflammable substances, is in general very feeble.

It will oxidize iron, zinc, copper, and arsenic, but has no action upon platina, gold, mercury, silver, lead, tin, antimony, and cobalt.

It combines with alkalies, alkaline earths, alumine, and metallic oxides, and forms the salts called *fluates*.

Fluoric acid has been discovered in the enamel of the human teeth, and in ivory. Vauquelin also found it in the topaz.

The only use to which fluoric acid has been applied, is that of etching upon glass. For this purpose, either the liquid fluoric acid may be employed, or the gas. If the former, the glass remains polished where the acid has corroded, but with the gas, the lines have the same appearance as if the glass had been ground and not polished. Landscapes and other designs properly executed upon glass by means of this acid, have an elegant appearance. The process is the same as that for etching upon copper, except that so much care is not necessary in preparing a ground; bees-wax alone will suffice.

Boracic Acid.

Boracic acid is procured from the salt called borax, in the following manner: the borax is dissolved in hot water, and the solution filtered; sulphuric acid is added very gradually to the solution, till it has a sensibly acid taste; being then left to cool, a number of small, shining, laminated crystals form in it; these crystals are the boracic acid; they are to be washed with cold water, and dried upon brown paper.

The crystals of the boracic acid are thin irregular hexagons, of a silvery whiteness. They are soft and unctuous to the touch, almost like spermaceti. They have no smell, but a bitterish

taste, with a slight degree of acidity; and they are unalterable in the air. When mixed with spirit of wine, they cause it to burn with a green flame. When sulphuric acid is poured upon them, a transient odour of musk is perceived.

Boracic acid, when exposed to a violent fire, is converted into a transparent glass; this glass is soluble in water, and the acid is again produced from it by evaporation.

It is much employed in analyzing minerals, as it brings almost all the stones into solution.

It has little or no effect in oxidizing any of the metals, except iron, zinc, and copper. It combines with alkalies, alkaline earths, alumine, and metallic oxides, forming the salts called *borates*.

The borax of commerce, is a borate of soda; it is used as a flux to vitrifiable earths, and to increase the fusibility of glass. It is also much used to promote the fusion of the harder kind of solders. As it swells up in losing its water of crystallization, the solder may be displaced, if not held down by wire or some other means; but if the salt be powdered, and deprived of its water of crystallization, before it is mixed with the solder, it will answer equally well, and be more conveniently managed.

Arsenic Acid.

The white oxide of arsenic, sold in the shops under the name of arsenic, is capable of combining with an additional dose of oxygen, and it then forms the *arsenic acid*. It may be obtained by simply mixing the white oxide of arsenic with oxymuriatic acid, and applying a heat sufficient to sublime the muriatic acid. It may also be obtained by the repeated sublimation of the white oxide, and renewing the air each time.

Arsenic acid does not crystallize; it has a sharp caustic taste, is thick, heavy, strongly poisonous, like all other preparations of arsenic; and very soluble in water, but fixed in the fire. It attracts humidity from the atmosphere, and at last becomes liquid. At the temperature of 60°, it dissolves in two-thirds of its weight of water. Its solution may be evaporated to dryness, and even converted into glass, which attracts moisture from the air, and acts powerfully on the crucible. Berthollet estimates the oxygen in this acid at one-tenth of the weight of the acid.

Arsenic acid does not act upon gold or platina, nor upon mercury or silver, unless assisted by a strong heat. It oxidizes copper, iron, lead, tin, zinc, bismuth, antimony, cobalt, nickel, manganese, and arsenic.

With different bases, this acid forms the salts called *arseniates*.

Arsenious Acid.

This is nothing more than the white oxide of arsenic sold in the shops, without any preparation. It has a weakly acid taste, and sensibly reddens the tincture of cabbage and litmus, and most other vegetable blues; the sirup of violets, which it turns green, is an exception. If thrown on burning coals, or a red-hot iron, it is volatilized in the form of a white vapour, which emits the smell of garlic. By a strong heat it is vitrified into a transparent glass. It only contains about seven per cent. of oxygen.

Arsenious acid is soluble in fifteen times its weight of boiling water, but requires for its solution eighty times its weight of cold water. The solution crystallizes best by slow evaporation; it is very acrid; it unites with the earthy bases, decomposes the alkaline sulphurets, and forms with them a yellow precipitate, in which the arsenic approaches to the metallic state.

The combinations of arsenious acid with different bases are called *arsenites*.

Tungstic Acid.

Tungstic acid is an oxide of tungsten. It is harsh to the touch, tasteless, and of a yellow colour. It is insoluble in water, and does not redden vegetable colours, till it has first been rendered soluble by being partly combined with ammonia. If exposed to the light, or strongly heated in close vessels, it becomes blue, and does not regain its yellow colour, except by calcination in the open air. Though ranked among the acids by several eminent chemists, its title to the character seems rather doubtful.—See page 405.

The compounds formed with this acid are called *tungstates*.

Molybdic Acid.

Molybdic acid is obtained from the ore or sulphuret of molybdenum, by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified, which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and leaves the molybdic acid in a state of purity.

Molybdic acid is a yellowish-white powder; it has an acrid but metallic taste. It is not altered in the air, and will bear a strong heat if the crucible be covered; but if the crucible be uncovered, the acid rises in the form of a white smoke. Its specific gravity is 3.75. It requires 570 times its weight of

water to dissolve it. The solution has a sour taste, coagulates solutions of soap, and precipitates alkaline sulphurets. Paper dipped in this acid becomes of a beautiful blue colour in the sun.

The molybdic acid has not been applied to any use in the arts, though experiments have been made which indicate that it may become useful in dyeing. Its combinations with different bases are called *molybdates*.

Molybdenous Acid.

Molybdena is susceptible of four different combinations with oxygen; at the lowest it is in the state of a black oxide; at the next it is blue, at the third it begins to assume acid properties, and is green. This is the *molybdenous acid*. The next dose of oxygen forms the yellowish white powder, which is the acid treated of in the last section.

Chromic Acid.

This acid is furnished by the mineral called the red lead ore of Siberia, which is a chromate of lead, and from which chromium is obtained. It also exists in the chromate of iron, which is more common than the former mineral, and in France is even abundant.

The acid is extracted from the real lead ore of Siberia, by boiling 100 parts of this mineral, with 300 of carbonate of potass, and 4000 of water, and separating the alkali by means of weak nitric acid. It is an orange-coloured powder, which has an acrid, metallic taste, is soluble in water, and crystallizable. If exposed to the action of light and heat, this powder loses oxygen and its acid properties, and is converted into the green oxide of chromium.

If the muriatic acid be distilled upon the chromic acid, it is oxygenized; and if simply mixed with the chromic acid, the same effect takes place, for it acquires the property of dissolving gold. This arises from the readiness with which chromic acid parts with its oxygen.

Chromic acid unites readily with alkalies. It also unites with borax, glass, and phosphoric acid, to which it communicates an emerald green colour.

Columbic Acid.

This acid is but little known; it is found in the ore of columbium, or *columbate of iron*.

Acetic Acid.

The acetic acid may be obtained from crystallized acetate of copper, which must be reduced to powder and distilled. A fluid possessing little acidity first rises, and afterwards a powerful acid. This acid has a greenish hue when first prepared, because a small part of the oxide of copper comes over with it; but it may be obtained perfectly colourless by distilling it with a gentle heat. It may also be prepared, with more certainty as to its freedom from copper, by distilling acetate of soda, or acetate of potass, with half its weight of sulphuric acid.

Acetic acid is sold in shops under the name of radical vinegar; it is transparent and colourless like water. Its smell is extremely pungent, and its taste acrid. When applied to the skin, it reddens and corrodes it. It is extremely volatile, wholly evaporating on exposure to the air; and when heated in the open air, it takes fire readily. At —50° it freezes. It unites with water in any proportion, and on mixture with it heat is evolved. It dissolves camphor, and, with the addition of essential oils, forms the *aromatic vinegar*.

Acetic acid is used for smelling at, crystals of sulphate of potass being put into a bottle, and moistened with it for this purpose. This mixture is called *volatile salt of vinegar*. A few drops of sulphuric acid, added to a phial of the acetate of potass, make a strong smelling bottle by the evolution of the acetic acid.

Acetic acid may be advantageously employed to separate manganese from iron. When both metals are dissolved in this acid, and the solution is evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese from the oxide of iron. Two or three evaporations and solutions are sufficient to remove the whole of its iron.

Acetic acid consists of oxygen, hydrogen, and carbon, but the proportions of its component parts have not been clearly proved; with various bases, it forms the salts called *acetates*.

Acetous Acid.

Acetous acid, or vinegar, has a yellowish colour, is perfectly limpid, has a pleasant smell, and a taste agreeably acid. By distillation it is rendered colourless, and its odour is improved. It is then called *distilled vinegar*. By exposure to heat, it evaporates entirely.

Distilled vinegar is pure acetous acid, if obtained by a gentle heat; but vinegar, as it is obtained at first after the acetous fermentation, contains mucilage and various impurities.

Lowitz prepared a concentrated acetous acid by congelation in the following manner: he froze as much as possible of a whole barrel of vinegar, then distilled the remaining unfrozen vinegar in a water-bath; by which means, at first especially, he collected the spirituous ethereal parts; of the vinegar, which next came over, he froze as much as possible, and afterwards purified it, by distilling it again with three or four pounds of charcoal powder. By this means he never failed to procure a very pure, sweet-smelling, highly concentrated acid; its agreeable odour was still further improved by the addition of a proper quantity of the ethereal liquor collected at the beginning of the first distillation, and which he had previously dephlegmated by two or three rectifications. After the distillation on the water-bath was over, that no acid might be lost, he removed the retort, with the charcoal powder which remained in it, to a sand-bath; and thus obtained, by means of a strong fire, a few ounces more of a remarkably concentrated acid, which was of a yellow colour.

Having collected about ten ounces of this concentrated acid, he exposed it to a cold equal to 195° of De Lisle's thermometer; in which situation it shot into crystals from every part. He let what remained fluid drop away from the crystals into a basin placed underneath, first in the cold air, and afterwards at the window within doors. There remained in the bottle, snow-white, finely foliated crystals, closely accumulated upon each other, which at first he took to be nothing but ice, but on placing them upon the warm stove, they dissolved into a fluid which was as limpid as water, had an uncommonly strong, highly pungent, and almost suffocating acetous smell, and in the temperature of 145° of De Lisle's thermometer, immediately congealed into a solid, white, crystallized mass, resembling camphor. The quantity of this glacial acid amounted to two ounces.

Cold acetous acid is capable of oxidizing iron, zinc, lead, nickel, tin, and copper, but does not attack these metals when hot.

It combines with alkalies, alkaline earths, alumine, magnesia, yttria, and strontian, with which it forms salts called *acetites*. The difference between these and the acetates, has not been much examined.

Acetous, like acetic acid, is composed of hydrogen, carbon, and oxygen, but the proportions of its component parts have not been correctly ascertained.

Malic Acid

Malic acid is found in the juice of unripe apples, in strawberries, and some other fruits; in apples it is the most abundant.

Scheele, who discovered this acid, obtained it in the following manner: he saturated the juice of apples with potass, and added a solution of acetate of lead till it no longer occasioned a precipitate. He then washed the precipitate carefully with a sufficient quantity of water; poured upon it diluted sulphuric acid till the mixture had a perfectly acid taste, without any of that sweetness which was perceptible as long as any lead remained dissolved in it; then separated by filtration the sulphate of lead, which had precipitated, and the malic acid thus obtained was concentrated by evaporation.

Malic acid, like other vegetable acids, is composed of hydrogen, carbon, and oxygen. It is a reddish-coloured liquid, strongly acid taste, and incapable of crystallization, but if boiled down to a thick consistence, it desiccates in layers like a shining varnish, by exposure to a dry air. It is easily decomposed by fire, and even when kept in bottles, it undergoes a spontaneous decomposition. It is altered by all the powerful acids, the sulphuric carbonizing it, and the nitric converting it into oxalic acid.

The malic acid precipitates mercury, lead, and silver, from the nitric acid, and also the solution of gold when diluted with water. The citric acid has no effect on these solutions.

The combination of the malic acid with various bases, forms the salts called *malates*.

The acid formerly called the *formic acid*, which is obtained by distilling the infusion of ants in boiling water, has now lost its rank as a distinct acid, as it is found to be only a mixture of the malic and acetic acids.

Oxalic Acid.

The oxalic acid exists in the juice of wood-sorrel, combined with potass; when prepared from this plant, it is sold under the name of *salt of lemons;* and is used as a substitute for the real juice of lemons. Sugar, and all other saccharine substances, contain the radical of the very same acid which wood-sorrel affords; it may be extracted from sugar in the following manner:

To six ounces of nitric acid in a tubulated retort, to which a large receiver is luted, add by degrees one ounce of lump sugar coarsely powdered. A gentle heat may be applied during the solution, and nitric oxide will be evolved in abun

dance. When the whole of the sugar is dissolved, distil off a part of the acid, till what remains in the retort has the consistence of sirup, and this will form regular crystals amounting to 58 parts from 100 of sugar. These crystals may be dissolved in water, recrystallized, and dried on blotting paper.

Honey, gum arabic, alcohol, the calculous concretions in the kidneys and bladders of animals, silk, wool, hair, and various other bodies, afford oxalic acid by distillation with nitric acid. Berthollet observes, that the quantity of the acid afforded by vegetable matters is in proportion to their nutritive qualities.

The crystals of oxalic acid effloresce in dry air, but attract a little humidity if it be damp; they are soluble in one part of hot, and two of cold water; and are decomposable by a red heat. When dissolved in 3600 times their weight of water, the solution still reddens litmus paper, and is perceptibly acid to the taste.

The oxalic acid is a good test for lime, for which it has a greater affinity than any other acid. It forms with lime an insoluble salt, not decomposable except by fire, and turning sirup of violets green.

Oxalic acid is capable of oxidizing lead, copper, iron, tin, bismuth, nickel, cobalt, zinc, and manganese.

The combinations of oxalic acid with the alkalies and other bases, form the salts called *oxalates*.

Citric Acid.

The citric acid is found in the juice of lemons, oranges, unripe grapes, and some other fruits. It is extremely acid to the taste, crystallizable, and very soluble in water: cold water dissolves rather more than its own weight of it, and hot water double its weight. The solution undergoes a spontaneous decomposition by long keeping.

If lemon juice be exposed in an open vessel, it deposits a quantity of mucilage, from which it may be separated by decantation and filtration. If the juice, thus purified, be exposed to a freezing temperature, and the ice formed in it, which consists only of its aqueous particles, be removed as it is formed, the lemon juice will be obtained in a state of high concentration. Its quantity will only be about one-eighth of what it was at first, but its strength will be eight times greater. It may be kept for use, or may be made into dry lemonade, by adding six times its weight of fine loaf sugar in powder.

The lemon juice, prepared as above, is not pure citric acid, but it retains a flavour which renders it better for domestic use

than if it were pure. To prepare pure citric acid, Scheele saturated lemon-juice with lime, edulcorated the precipitate, which consisted of citric acid and lime, separated the lime from it by diluted sulphuric acid, cleared it from the sulphate of lime by repeated filtrations and evaporations; then evaporated it to the consistence of a sirup, and set it in a cool place: a quantity of crystals formed, which were pure citrid acid.

Citric acid oxidizes iron, zinc, and tin. It does not act upon gold, silver, platina, mercury, bismuth, antimony, and arsenic.

The combinations of the citric acid with different bases, are called *citrates*.

Tartaric Acid.

A hard substance is found adhering to the sides of casks in which some kinds of wine have been fermented: this substance is tinged with the colour of the wine, but when it has been purified by solution, filtration, and crystallization, it constitutes the salt called *cream of tartar*. Cream of tartar consists of potass united to a peculiar acid; this acid is the *tartaric acid*. Cream of tartar is a *supertartate of potass*.

To obtain tartaric acid, four parts of the supertartrate of potass may be boiled in twenty parts of water, and one part of sulphuric acid added gradually. By continuing the boiling, the sulphate of potass will fall down. When the liquor is reduced to one-half, it is to be filtered, and if any more sulphate be deposited by continuing the boiling, the filtering must be repeated. When no more is thrown down, the liquor is to be evaporated to the consistence of a sirup; and thus crystals of tartaric acid, equal to half the weight of the tartar employed, will be obtained. These crystals readily dissolve in water, and the solution crystallizes by evaporation.

The tartaric acid does not oxidize platina, gold, silver, lead, bismuth, or tin; and its action on antimony and nickel is very slight.

It unites with the alkalies, and most of the earths. The salts formed with it are called *tartrates*.

The supertartrate of potass, from which this acid is obtained, is much used in medicine; it is cooling, and gently aperient; in domestic economy it is dissolved in water, and, with the addition of a little sugar and a few slices of lemon, forms, after standing a day or two, an agreeable beverage called *imperial water*. An infusion of green balm, used instead of water, improves this liquor.

Mixed with an *equal* weight of nitre, and thrown into a red-hot crucible, supertartrate of potass detonates, and forms the *white flux*; with half its weight of nitre, it forms the *black flux*; and by simple mixture with nitre in various proportions, it is called *raw flux*. It is likewise used in dyeing, gilding, whitening pins, and other arts.

Benzoic Acid.

This acid is obtained from the resin called *benzoin* or *benjamin*, which is brought from the East Indies. By a gentle heat the resin is sublimed, and condenses in the form of long needles, or straight filaments of a white colour, crossing each other in all directions. These are what are sold under the name of *flowers of benjamin*, and consist of the acid in question. When pure, they are of a brilliant white, have an aromatic odour, are entirely soluble in alcohol, but the addition of water causes a precipitate. Hot water dissolves them copiously, but cold water scarcely at all. They are not altered by the air; their taste is acrid and bitter. They form a kind of paste if rubbed in a mortar.

The purest benzoic acid may be obtained in the humid way, by boiling the resin with carbonate of soda, and adding diluted sulphuric acid to the filtered decoction as long as it produces any precipitation. The precipitate is the benzoic acid.

Benzoic acid is so inflammable, that it burns with a clear yellow flame, without the assistance of a wick. The mineral acids dissolve it, but it separates from them without alteration, by the addition of water. It dissolves in oils and melted tallow. It unites with earthy and alkaline bases, forming the salts called *benzoates*.

Camphoric Acid.

Camphor is a concrete essential oil, of a strong taste and smell; it is extracted by sublimation from a species of laurel in the East Indies, and has a crystalline form. It is so volatile, that it cannot be melted in open vessels, and so inflammable, that it burns even on the surface of water. Kosegarten, by distilling nitric acid eight times successively from this substance, obtained an acid in crystals, which is called *camphoric acid*.

Camphoric acid is in snow-white crystals, which effloresce in the air. It has a slightly acid, bitter taste, and a smell like saffron. It reddens vegetable blues. It requires 200 times its weight of cold water to dissolve it; but boiling water takes up one-twelfth. If thrown upon burning coals, it is entirely

dissipated in a thick aromatic smoke. With a gentle heat it melts and is sublimed. It is soluble in alcohol, and not precipitated from it by the addition of water, a property which distinguishes it from the benzoic acid. It does not precipitate lime from lime-water.

The mineral acids dissolve camphoric acid entirely; it is also dissolved by the fixed and volatile oils. It unites readily with the earths and alkalies, forming the salts called *camphorates*.

Gallic Acid.

This acid is found in the nut-gall, and generally in all astringent vegetables, though it exists independently of the astringent principle. The nut-gall is an excrescence produced on a species of oak by the puncture of an insect.

The gallic acid may be obtained by various processes; the following method is proposed by Proust. Pour a solution of muriate of tin into an infusion of nut-galls; a copious yellow precipitate is instantly formed, consisting of the tanning principle combined with the oxide of tin. After diluting the liquor with a sufficient quantity of water, to separate any portion of this precipitate which the acids might hold in solution, the precipitate is to be separated by filtration. The liquid contains gallic acid, muriatic acid, and muriate of tin. To separate the tin, a quantity of sulphuretted hydrogen gas is to be mixed with the liquid. Sulphuret of oxide of tin is precipitated under the form of a brown powder. The liquid is then to be exposed for some days to the light, covered with paper, till the superfluous sulphuretted hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and left to cool. Crystals of gallic acid are deposited. These are to be separated by filtration, and washed with a little cold water. The evaporation of the rest of the liquid is to be repeated till all the gallic acid is obtained from it.

The gallic acid thus obtained has a very acid taste; it reddens vegetable blues; dissolves in 1½ part of boiling water, and twelve parts of cold water. Alcohol dissolves one-fourth of its weight in the cold, and its own weight if assisted by heat.

Gallic acid, thrown upon burning coals, inflames, and emits an aromatic odour, not very dissimilar to that of the benzoic acid. Its residuum is charcoal. It is decomposed by distillation. It has a great affinity for most of the metallic oxides, which it will take from the strongest acids. A solution of gold it renders green, and causes a brown precipitate which readily passes to the metallic state. On the nitric solution of silver it has the

same effect. Mercury it precipitates of an orange yellow; copper, brown; bismuth, of a lemon colour; lead, white; iron, purple or black, for which reason nut-galls are employed to form writing ink; they are also extensively used in dyeing. Platina, zinc, tin, cobalt, and manganese, it does not precipitate.

The combination of the gallic acid with different bases, are called *gallates*.

Succinic Acid.

This acid is obtained from amber, which is a brown, transparent, combustible substance, dug out of the earth, in some countries, and found upon the sea-coast in others.

During the distillation of amber, the crystals of this acid attach themselves to the neck of the retort; they were formerly called *salt of amber*. When purified by repeated solution in hot water, filtration, and re-crystallization, they are white, shining, triangular prisms. Their taste is slightly acid; they redden tincture of litmus, but have no effect on sirup of violets.

This acid obtains its name from *succinum*, the Latin name of amber; its salts are called *succinates*.

Suberic Acid.

This acid exists in cork. It is obtained by distilling nitric acid off cork grated to powder, till the cork acquires the consistence of wax, and no more red fumes appear. The residuum is placed in a sand-heat, and continually stirred, till white penetrating vapours appear. It is then removed from the sand-heat, and stirred till cold. Boiling water is poured upon the product; heat is applied till it liquefies, and it is then filtered. A sediment is deposited, which must be separated by the filter, and the fluid evaporated nearly to dryness. The mass thus obtained is the *suberic acid*. It may be further purified by saturating it with potass, and precipitating it by means of an acid; or by boiling it along with charcoal powder.

Suberic acid is not crystallizable; boiling water dissolves half its weight of it, but it is nearly insoluble in cold water. Its taste is acid, and slightly bitter. It reddens most vegetable blues, but has the peculiar property of changing the solution of indigo in sulphuric acid to a green.

It attracts moisture from the atmosphere, and exposure to light renders it brown. It has no action on gold or nickel, but oxidizes most of the other metals. With different bases, its salts are called *suberates*.

Phosphoric Acid.

The purest phosphoric acid is obtained by the combustion of phosphorus in oxygen gas. If no moisture be present, it is obtained in the form of white flocks, which are very light, and have a strongly acid taste. These flocks will attract moisture from the atmosphere, and become a fluid acid. This acid may be concentrated till its specific gravity exceeds that of the sulphuric acid; though strongly acrid, it is not corrosive, and has no smell.

Phosphoric acid may likewise be obtained by heating phosphorus with nitric or sulphuric acid; it remains in the retort, after these acids are driven over. Another mode of forming it, consists in exposing phosphorus for some weeks to the common temperature of the atmosphere, by which means it is gradually converted into a liquid acid. It is usually placed on the inclined side of a funnel, through which the liquid which is formed drops into a bottle placed beneath to receive it, and containing a little distilled water. The acid thus prepared, is called *phosphoric acid by deliquescence.*

The quantity of acid obtained from phosphorus, is generally about three times the weight of the phosphorus used.

If phosphoric acid be exposed to heat, it gradually becomes thick and glutinous; and if the heat be continued, it melts into a kind of glass, which is called the *glacial* acid of phosphorus, or glacial phosphoric acid. This glacial acid becomes liquid by exposure to the atmosphere.

Phosphoric acid, when perfectly dry, sublimes in close vessels, but the addition of water deprives it of this property. If mixed with charcoal, or other inflammable matter, and exposed to a strong heat, it parts with its oxygen, and is converted into phosphorus.

* Phosphoric acid, assisted by heat, has some action upon silex, and will therefore decompose glass.

The salts of phosphorus are called *phosphates.* The phosphate of lime exists in bones, from which phosphorus is generally prepared; whole mountains of phosphate of lime are said to exist in the province of Estramadura in Spain.

Phosphorous Acid.

The spontaneous combustion of phosphorus at the temperature of the atmosphere, forms, in the first instance, *phosphorous acid,* which contains less oxygen than the phosphoric; but as phosphorous acid acquires an additional quantity of oxygen from the atmosphere, it is speedily converted into the phosphoric.

Phosphorous acid is, therefore, very little known. It may be decomposed by charcoal, but cannot be reduced to the glacial state. Its salts are called *phosphites.*

Bombic Acid.

This acid Chaussier obtained from the silk-worm, by bruising the insect, and infusing it in alcohol. On evaporating part of the alcohol, he obtained a pungent yellow fluid, which reddened vegetable blues, and united with alkalies, and some of the earths. It has been very little examined.

Sebacic Acid.

Sebacic acid exists in tallow and animal fat generally. It is liquid, fuming, and of a penetrating odour; it has an acid, sharp, bitterish taste. It reddens tincture of litmus. Heat decomposes it, turning it yellow, and reducing it to a coal. It crystallizes in needles, and its crystals, when heated, liquefy like tallow. It produces an ether by distillation with alcohol.

Sebacic acid may be procured by heating together a mixture of suet and lime. Sebate of lime is formed, which may be purified by solution in water. It is then to be put into a retort, and sulphuric acid poured upon it; the sebacic acid passes over, on the application of heat.

Sebacic acid oxidizes silver, mercury, copper, iron, lead, tin, zinc, antimony, and manganese; but has no action on bismuth, cobalt, and nickel. When mixed with nitric acid, it dissolves gold.

Salts formed with the sebacic acid, are called *sebates.*

Laccic Acid.

This acid is obtained from a substance called *white lac*, which resembles bees' wax, and is brought from the East Indies. It is the produce of an insect.

Dr. Pearson, in preparing to examine white lac, exposed 2000 grains of it to a degree of heat just sufficient to melt them. As they grew soft and fluid, there oozed out 550 grains of a reddish watery liquid, which had the smell of newly baked bread. To this liquid he gave the name of *laccic acid.*

The laccic acid reddens paper stained with tincture of litmus; it has a slightly saltish taste, but no sourness; when heated, it smells like newly baked hot bread; at the temperature of 60°, its specific gravity is 1.025. After a slight evaporation, it crystallizes. It is converted into vapour at the heat of 200°, and leaves only a small quantity of extractive matter behind.

Amniotic Acid.

If the liquor of the amnious of a cow be evaporated to one-fourth, the remainder will afford crystals, on being left to cool. These crystals are the *amniotic acid.* They are not quite pure, but may be purified by solution in water, and re-crystallization; the crystals are then white and shining.

The amniotic acid is slightly sour; it reddens the tincture of litmus; it readily dissolves in hot water, but very sparingly in cold water. It is soluble in alcohol. The acids precipitate it from its combinations with alkalies in a white crystalline powder.

Lactic Acid.

This is the acid which appears in milk that has become sour. To obtain it by Scheele's process, evaporate a quantity of sour whey to an eighth part, and then filter it; this separates the cheesy part. Saturate the liquid with lime-water, and the phosphate of lime precipitates. Filter again, and dilute the liquid with three times its own bulk of water; add to it oxalic acid, drop by drop, to precipitate the lime which it has dissolved from the lime-water; then add a very small quantity of lime-water, to see whether too much oxalic acid has been added. If there has, oxalate of lime immediately precipitates. Evaporate the solution to the consistence of honey, pour in a sufficient quantity of alcohol, and filter again; the acid passes through dissolved in the alcohol, but the sugar of milk, and every other substance, remains behind. Add to the solution a small quantity of water, and distil with a low heat; the alcohol passes over, and leaves behind the lactic acid dissolved in water.

Lactic acid is incapable of crystallizing; when evaporated to dryness, it deliquesces in the air. Its salts are called *lactates.*

Mucous Acid.

This acid is obtained from gum arabic, and other mucilaginous substances. Scheele, its discoverer, obtained it from sugar of milk, and therefore called it the *acid of sugar of milk;* it was afterwards called *saccholactic acid,* which has been exchanged for its present title.

If one part of gum be gently heated with two of nitric acid, till a small quantity of nitrous gas, and of carbonic acid, are disengaged, the dissolved mass will, on cooling, deposit the mucous acid.

Mucous acid forms a white gritty powder, which has a slightly acid taste. It is soluble in 60 times its weight of

boiling water. The solution reddens tincture of litmus. Its specific gravity at 53.7°, is 1.0015.

The combinations of this acid with other bodies are called *mucites.*

Uric Acid.

Scheele, in analyzing human calculi, found that a peculiar acid constituted the greater part of them all, and nearly the whole of some. This acid is called *uric* or *lithic acid*. It exists in human urine, from which it spontaneously separates in a few days in the form of red crystals with brilliant facets, the urine at the same time losing its colour and acid nature. It has neither taste nor smell, but reddens vegetable blues. It is soluble in 2000 times its weight of cold water. It is a composition of carbon, nitrogen, hydrogen, and oxygen.

This acid is found in the urine of the camel, and in those anthritic concretions commonly called chalkstones.

Prussic Acid.

This acid exists, combined with iron, in the fine blue pigment well known by the name of *Prussian blue*. It may be obtained as follows: Mix four ounces of prussian blue with two of red oxide of mercury prepared by nitric acid, and boil them in twelve ounces by weight of water, till the whole becomes colourless; filter the liquor, and add to it one ounce of clean iron filings, and six or seven drachms of sulphuric acid. Draw off by distillation about a fourth of the liquor, which will be prussic acid; though, as it is liable to be contaminated with a portion of sulphuric acid, to render it pure it may be rectified by re-distilling it off carbonate of lime.

The prussic acid has a smell like that of peach blossoms. Its taste is at first sweetish, then acid and hot, and it excites coughing. It is very volatile, and capable of existing as an acid in the gaseous form.

The prussic acid combines with earths, alkalies, and metallic oxides, forming the salts called *prussiates*. The prussiate of potash and iron, often called the prussian alkali, is one of the most important of these compounds, both for its utility as a test, and for making prussian blue. To form it, two parts of bullock's blood, and one of potash, are calcined by a moderate heat in a covered crucible, containing a hole in the lid. The calcination is to be discontinued when the matter ceases to afford a small blue flame. The residuum must be lixiviated with a small quantity of cold water. In this state, the prussiate of potass may be employed for making prussian blue, though not pure enough for the use of the chemist. Henry

recommends it to be obtained by the following process from prussian blue, when required quite pure: To a solution of potass, deprived of its carbonic acid by quicklime, and heated nearly to the boiling point, add by degrees powdered prussian blue, till its colour ceases to be discharged. Filter the liquor, wash the sediment with water, till it ceases to extract any thing, mix the washings together, and pour the mixture into an earthen dish in a sand-heat. When the solution has become hot, add a little diluted sulphuric acid, and continue the heat about an hour. A copious precipitate of prussian blue will be formed, which must be separated by filtration. Assay a small quantity of the filtered liquor in a wine-glass, with a little diluted sulphuric acid. If an abundant production of prussian blue still take place, the whole liquor must be exposed again to heat with a little diluted sulphuric acid, and this must be repeated as often as necessary. Into the liquor thus far purified, pour a solution of sulphate of copper in four or six times its weight of warm water, as long as a reddish brown precipitate continues to appear. Wash this precipitate, which is a prussiate of copper, with repeated affusions of warm water; and when the water comes off colourless, lay the precipitate on a linen filter to drain, after which it may be dried on a chalkstone. When the precipitate is dry, powder it, and add it by degrees to a solution of potass, which will take the prussic acid from the oxide of copper. This prussiate of potass, however, will be contaminated by some portion of sulphate of potass, from part of which it may be freed by gentle evaporation, as the sulphate crystallizes first. To the remaining liquor, add a solution of barytes in warm water, as long as a white precipitate ensues, observing not to add more after its cessation. The solution of prussiate of potass will now be freed in a great measure from iron, and entirely from sulphate, and by gentle evaporation will form, on cooling, beautiful crystals. These, dissolved in cold water, afford the purest prussian alkali that can be prepared. If pure barytes be not at hand, acetate of barytes may be used instead; as the acetate of potass formed, not being crystallizable, will remain in the mother-water.—See page 480, of this volume, for an account of the utility of this prussiate.

Prussiates of soda and of ammonia may be prepared in a similar way to the prussiate of potass, above described.

Of Oxides.

When the oxygen united to any of the simple substances does not give it the properties of an acid or an alkali, the compound is called an *oxide*.

Most of the metals are capable of combining with different proportions of oxygen, and a difference in the proportion of oxygen gives a different colour to the oxide.

Some oxides require only an additional quantity of oxygen to convert them into acids; others always retain the character of oxides, whether possessed of the highest or the lowest quantity of oxygen with which they will combine.

Oxides cannot be formed except oxygen be present, and the oxide of any substance is heavier than the substance itself, by a quantity exactly equal to the oxygen received. The young student may be reminded, that by the term heavier, it is not meant that the density or specific gravity of the oxide is greater than its base, but the total quantity of it weighs more.

Oxides are in general friable or pulverulent, and have the appearance of earths; but one of them is a fluid, and some of them are gases.

Oxides of Nitrogen.

Nitrogen combines in two proportions with oxygen without producing an acid; it therefore furnishes two oxides, which are distinguished from each other, like the acids, by a difference in the termination of the word denoting the base: they are the *nitrous oxide*, and *nitric oxide*.

Nitrous oxide.—This gas, which is also known by the name of the *gaseous oxide of nitrogen*, is composed of 63 parts of nitrogen, and 37 of oxygen by weight. It has a faint smell, and imparts a slight sensation of sweetness when respired. It is dissolved by water, but may be expelled from the water by heat unchanged. Alcohol absorbs more of it than water, and the essential and fixed oils more than alcohol; but heat expels it from all these combinations. It supports combustion with more activity than common air; but it is in general necessary that the combustible should be kindled in the atmosphere or oxygen. It may be respired for a few minutes, and the extraordinary effects it produces on the system, during its respiration, and for a short time after, occasions it to be frequently made for this purpose, which is the only use, (if it may be called a use,) to which it has been applied. To inhale it, superinduces a species of intoxication; the mind of the

person is lost for the moment, to a right consciousness of things around him; in general he laughs involuntarily and extravagantly; exhibits the most frantic or preposterous gesticulations, and violent muscular exertion, and feels at the same time delightfully happy. In a few moments, after having ceased to breathe the gas, its effects go off. With nearly all persons who have breathed this gas, not the least uneasiness or languor subsequently remains; it has even recovered some from a state of casual debility, and restored them to comfortable enjoyment; but as there are others on whom less favourable effects have been produced, it may be a useful caution for those who have never breathed it, or who are not in perfect health, to take in the first instance but a small dose.

As it is important that the nitrous oxide intended to be inhaled should be perfectly pure, it may be proper to observe, that it can only be prepared with certainty by the decomposition of nitrate of ammonia. For this purpose, nitric acid, diluted with five or six parts of water, may be saturated with carbonate of ammonia, and the solution evaporated by a very gentle heat, adding occasionally a little of the carbonate, to supply what is carried off. The nitrate crystallizes in a fibrous mass, unless the evaporation has been carried so far as to leave it dry and compact. The nitrate should be put into a retort, and a lamp furnace should be employed to decompose it, as the heat employed should not be raised above 450°. A pound of the nitrate of ammonia will yield about 5 cubical feet of the gas, which should be received over water, and afterwards allowed to stand an hour or two in contact with the water, which will absorb any ammonia that may have been sublimed, or any acid that may happen to be present.

Nitric oxide, (sometimes called *nitrous gas*.)—This gas is composed of 44 parts of nitrogen, and 56 of oxygen by weight. It is an invisible gas, until it comes in contact with the atmosphere, or some air which contains oxygen, when it assumes an orange colour. It is interesting to observe the difference between this gas, and the preceding, from which it only differs in containing a few parts more oxygen;—this gas instantly kills the animals which breathe it, and even destroys plants. In general also, it extinguishes light, but some substances have the property of decomposing it, if inflamed before being put into it, and of then burning with considerable splendour.

Dr. Priestley found that water was capable of absorbing about one-tenth of nitric oxide, from which it acquired an astringent taste; and that the water gave out the whole of this gas when passing to the state of ice.

Oils greedily absorb nitric oxide, and decompose it. Nitric acid also absorbs it, and is converted by the absorption into nitrous acid, becoming fuming and coloured at the same time.

Nitric acid is composed of 75 parts of oxygen and 25 of nitrogen; it therefore bears a very near relation to this gas, which may be converted into it, by simply mixing it with a due proportion of oxygen.

Oxide of Hydrogen.

Hydrogen appears to be capable of combining with oxygen only in one proportion, and that one forms water, which is the *oxide of hydrogen.*

Carbonic Oxide.

Carbon, combined with 60 per cent. of oxygen, forms *carbonic oxide*, which is an invisible and elastic gas, of rather less specific gravity than common air. This gas is not fit for respiration, nor will it support combustion; but it will itself burn, with a lambent blue flame, in atmospheric air. This is the only oxide of carbon which has been obtained.

Oxide of Sulphur.

Sulphur, if kept for some time in fusion in an open vessel, absorbs about 2.4 per cent. of oxygen. This is the only oxide of it which is known; it is of a red colour, and is used for taking impressions of medals.

Oxide of Phosphorus.

The brown colour which phosphorus acquires by exposure to the air, is in consequence of its combination with oxygen, and this brown part is the *oxide of phosphorus.* Phosphorus, when mixed with its oxide, which it generally is when newly prepared, may be purified by putting it into hot water; the oxide swims on the surface.

Metallic Oxides.

Metallic oxides are exceedingly numerous; every metal is capable of forming at least one oxide, and most metals are capable of forming several by combining with different proportions of oxygen. The oxygen which enters into their composition, has the singular effect of depriving them entirely of their lustre and cohesion, and reducing them to the state of earths.

An acid has no action upon a metal, unless the oxygen it contains has a greater attraction for the metal put into it, than

for the base of the acid. The acids first impart oxygen to metals, and then dissolve the oxide.

The metals, in the readiness with which they imbibe oxygen, and the firmness with which they retain it, differ very considerably. From some, as manganese, it cannot be separated without difficulty; from others, as gold, silver, and platina, it is ever ready to separate, because of their slight affinity for it, which constitutes their disposition to resume their metallic state, and is the leading property of what are called noble metals.

From the beauty and fixedness of the colours of many of the metallic oxides, they are used as pigments in painting in oil and water colours; and as they are convertible into glass, they are admirably adapted for painting on enamel and porcelain. A purple colour is given by gold; yellow by silver; green by copper; red by iron; blue by cobalt; and violet by manganese.

As carbon and hydrogen have a stronger attraction for oxygen than other substances, they, or the substances consisting chiefly of them, are employed for reducing metallic oxides; the metallic oxide is mixed up with charcoal, oil, fat, resin, or the cheapest inflammable body which can be obtained, and submitted in a crucible to a strong heat; the oxygen of the oxide combines with the hydrogen or carbon which is present, and the metal is obtained in its metallic state at the bottom of the crucible.

Of Earths.

The rocks, stones, and mould, which constitute the bulk of the globe, are found, upon being chemically examined, to consist of a few substances, which are distinctly different from each other, though they have several properties in common. These substances are called *earths*.

1. Earths are incombustible, and when alone are scarcely alterable by the most intense heat.

2. They are either insoluble or very sparingly soluble in water or alcohol; when in combination with carbonic acid, they are insoluble.

3. Their specific gravity is never five times greater than that of water.

4. They assume the form of a white dry powder, when pure.

5. They have little taste or smell, at least when combined with carbonic acid.

6. They are not precipitated from their solutions in acids, by the prussiate of potass, like metallic oxides.

The earths have a very considerable resemblance to metallic oxides, and Baron Born long ago surmised that they were compound bodies; but as no proof of this opinion could be advanced, they were classed as if they were simple, till Sir H. Davy, having succeeded in decomposing the alkalies, submitted the earths to the same powerful means of analysis, and succeeded in decomposing most of them. From his experiments they must be considered as metallic oxides; but their metallic bases, like those of the alkalies, have so powerful an attraction for oxygen, as to be wholly inseparable from it by the ordinary means of operation; and from the extreme difficulty of obtaining and preserving them, little is known of their properties.

The distinct earths, at present known, are the nine following:

1. Alumine,
2. Silex,
3. Magnesia,
4. Zircon,
5. Glucine,
6. Yttria,
7. Lime,
8. Barytes,
9. Strontian.

The three last-named earths, viz. lime, barytes, and strontian, having, when pure, a caustic taste, solubility in water, and the effect of changing blue vegetable tinctures, to a green, are often called *alkaline earths,* and have sometimes been classed among the alkalies; but as they are infusible by themselves, and form insoluble compounds with carbonic acid, they certainly have a nearer relation to the general properties of the earths than to the alkalies.

Alumine.

Alumine has neither smell nor taste while dry; it is soft to the touch, and adheres strongly to the tongue; by exposure to an intense heat, it is imperfectly fused, and becomes so hard as to strike fire with steel, and to be capable of cutting glass. Its specific gravity is 2.00. It is scarcely soluble in water; but when dry, it is capable of absorbing 2½ times its weight of water, and easily mixes with a greater quantity to form a paste: it is soluble in all the acids, and in solutions of caustic potass and soda. It is often called *argil* or *pure clay.*

Alumine derives its name from alum, from which salt it is obtained in the greatest purity. Common alum is a sulphate of alumine; common clay is alumine mixed with silex, and several other bodies.

Ignition renders alumine incapable of forming a paste with water; but it recovers this property by solution and precipitation.

To obtain alumine, dissolve alum in hot water, and add ammonia or potass to the solution, as long as any precipitate is formed. Decant off the fluid, and wash the precipitate in a large quantity of water. This precipitate is alumine, combined with only a small portion of sulphuric acid, whereas in the state of alum, it was supersaturated with the acid. If this precipitate be dissolved in muriatic acid; the solution evaporated till it deposits crystals in cooling; these crystals separated each time after repeated concentrations of the solution; and lastly, a precipitate formed by ammonia, alumine nearly pure will be obtained; the crystals separated consisting of the alum.

Alumine cannot be artificially crystallized; but it is found native in beautiful transparent crystals, of great hardness, and of the specific gravity of 4. In this state it forms the precious stone called *sapphire*.

Though alumine alone is prodigiously refractory in the fire, yet it easily fuses and enters into combination with lime, for which it has a strong affinity.

Alumine has also a strong affinity for metallic oxides, particularly those which contain most oxygen. The various colours of clay are mostly owing to the oxide of iron combined with them.

Alumine is of great importance to mankind; it enters largely into the composition of the best arable soils; as it swells and will not permit water to sink through it, it is inestimable as a lining for canals and reservoirs; for this purpose it is used in the state of clay; combining readily with greasy substances, it is also of the first importance in scouring cloth, to which use it is often applied in the form of pipe-clay, but, in manufactures, fuller's earth is chiefly used, which is alumine mixed with very fine silex. Clay is also extensively required for making bricks and tiles. Alumine is the base of all earthenware and porcelain, and its utility for these purposes renders it of great consequence. In one province of China, five hundred furnaces, and nearly a million of men, are said to be employed in the manufacture of porcelain.

Achard found that equal parts of alumine, lime, magnesia, and silex, melted into glass. They were fusible also in various other proportions, especially where the silex predominated.

The attempts of Sir H. Davy to decompose alumine, indicated it to be a compound body, but were not so decisive as with some of the other earths.

Silex.

Silex, in its purest state, is a white powder, possessing a singular degree of asperity when rubbed between the fingers. It has neither taste nor smell; its crystals scratch glass. It is insoluble in water by artificial means, and in all the acids except the fluoric. Alone, it is unalterable by the strongest heat; but when mixed with potass or soda, it enters into fusion, and forms glass. Its specific gravity is 2.65.

Silex exists almost in a state of purity in rock crystal; it forms also the principal part of flints, and of nearly all stones which strike fire with steel.

If flints, or rock crystal, or quartz, (which is rock crystal coloured,) be fused with three or four times its weight of potass, a mass, resembling glass, will be obtained. This glass will absorb moisture from the atmosphere, and is entirely soluble in water. The solution is called *liquor silicum*, or *liquor of flints*.

If an acid, the muriatic for example, be poured into the liquor of flints, it combines with the alkali, and the silex is precipitated. The silex thus obtained must be purified from saline admixture, by repeatedly washing it in distilled water. The rock crystal, or flint, to render it more easily acted upon by the alkali, should be made red-hot in the fire, and plunged in that state into water. It may then be easily reduced to powder.

Equal parts of lime and silex may be fused and vitrified; but the mass is not transparent. Barytes and silex also enter into fusion, when the barytes predominates.

Silex constitutes the principal part of the stone called asbestos, which has a fibrous texture, and was by the ancients manufactured into cloth. In this cloth, which has the property of not being consumed by fire, they wrapped the bodies of the dead, in order to preserve their ashes, when the body was burnt. But though asbestos-cloth is whitened and not destroyed by the heat of a common fire, it is rendered less flexible, and reduced in weight. Asbestos is found in Corsica, in the Isle of Elba, in Sweden, and in Cornwall and Anglesea, in England.

The clearest glass is made of the finest white sand fused with purified alkali, of which the proportion is not more than one-half of that of the sand. The common bottle-glass is not made with pure alkali, but with the ashes of vegetables, or soap-boiler's waste ashes. The green colour is derived from the iron usually contained in the ashes of vegetables. If glass contain a considerable excess of alkali, it will attract moisture from the atmosphere, and in a short time become fluid; and

even a small excess of alkali will cause it to lose its transparency.

Alkalies in the humid way are capable of dissolving one-sixth of their weight of silex, when the earth is in a state of minute division.

Silex and alumine are the earths which have the greatest affinity for each other; and they predominate over all other earths, both in quantity, and the hardness of the compounds they form.

Magnesia.

Magnesia is a soft white powder, very light, and resembling vegetable fecula. It has scarcely any smell, but a slightly bitter taste, is unalterable in the fire, and requires at least 8000 parts of water to dissolve it. Its specific gravity is 2.33. It gives a slightly green tinge to vegetable blues. It cannot be fused alone by the strongest fires, but it remarkably promotes the fusion of some other substances.

Magnesia has the singular property of rendering opium and resins soluble in water.

This earth has never been found native; but always in combination with some acid; in combination with the sulphuric acid it exists in sea-water, and in the water of many springs, particularly some about Epsom, from which circumstance the sulphate of magnesia was called Epsom salt. To obtain the earth, dissolve Epsom salt in water, and add half its weight of potass. The magnesia is immediately precipitated, and after having been thoroughly washed with water, it may be dried. The Epsom salt of commerce, is generally procured from the waters which remain after the separation of salt from sea-water, by adding to it sulphate of iron. The sulphuric acid leaves the iron to unite with the magnesia, and the muriatic acid which was before combined with it unites with the iron.

Stones which contain a considerable proportion of magnesia, are unctuous to the touch, have a fibrous texture, and a silky lustre, the green steatites or French chalk, and talc, are examples.

In the state of phosphate, magnesia has been found in the bones of all animals. A proportion of magnesia is necessary in the clays designed for making the best porcelain; it lessens the contraction to which clay is subject.

Sir H. Davy succeeded in separating the metallic base of magnesia: it sunk rapidly in water, producing magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a white powder, which proved to be magnesia.

Magnesia would in bleaching be preferred to lime for combining with the oxymuriatic acid, but it is too expensive. It is much used in medicine, as a gentle aperient, and corrector of acidity; as an aperient it should be in the state of a carbonate, or what is called mild magnesia, or magnesia alba; as a corrector of acidity, it will not be very effectual unless pure, in which state it is sold under the name of *calcined magnesia*.

If sulphur and magnesia be kept for some time in a moderate heat, they combine, and form the *sulphuret of magnesia*, which is decomposed by exposure to the air.

Kirwan found that 30 parts of lime and 10 of magnesia, by a heat of 150° of Wedgwood, was converted into a fine greenish yellow glass, but the crucible was corroded; and the mixture of these two earths often penetrates the crucible.

The salts formed by magnesia with acids, are mostly very soluble in water, are crystallizable, and have a bitter taste.

Zircon.

Zircon is destitute of taste and smell, and is harsh to the touch. If kneaded with water, and gradually dried, it assumes an appearance almost like gum arabic, and retains one-third of its weight of water.

It is soluble in the acids, and alkaline carbonates, but differs from all the other earths in not being soluble in pure alkalies. If heated to whiteness, it is not afterwards soluble in the acids.

By the heat of a forge, it may be converted into a semi-vitreous mass, resembling porcelain. In this state it will strike fire with steel, and has a specific gravity of 4.3.

Zircon was first obtained by Klaproth from the jargon of Ceylon. It has since been found in the jacinth. It is a scarce earth, and has not been applied to any use. Sir H. Davy succeeded partially in the decomposition of this and the following earth.

Glucine.

Glucine is a soft white powder, without taste or smell; it resembles alumine in adhering to the tongue, but differs from that earth, in forming soluble sweet-tasted salts, which are slightly astringent; it is infusible, neither hardens, shrinks, or agglutinates by heat. It is insoluble in water, but forms with it a slightly ductile paste.

Glucine, like alumine, is soluble in pure liquid fixed alkalies, but not in pure ammonia, though soluble in carbonate of ammonia. It unites with sulphuretted hydrogen.

This earth was first obtained from the aqua marina, and afterwards from the beryl or emerald, which contains 16 per cent. of it. Vanquelin, who discovered it, is of opinion that it may be serviceable as a mordant in dyeing, and also in medicine, when it shall be obtained in greater plenty.

Yttria.

Yttria is a fine white powder, without taste or smell. It is the heaviest of all the earths, its specific gravity being 4.842. It is infusible alone, but with borax it melts into glass, which is transparent, unless the borax be in excess, when it becomes white and opake. The salts formed by this earth, which is soluble in most of the acids, have a sweetish taste, and are coloured.

Yttria is insoluble in water, and in caustic fixed alkalies, but it dissolves in carbonate of ammonia, though it requires at least five times as much as glucine. The oxalic acid, and oxalate of ammonia, form precipitates in its solutions resembling the muriate of silver. Prussiate of potass, crystallized and redissolved in water, throws it down in white grains; phosphate of soda, in white gelatinous flakes; infusion of galls, in brown flocks.

This earth is obtained from a mineral called *gadolinite*, from Gadolin, the name of the chemist who first discovered this earth. Gadolinite is found at Ytterby, in Sweden. It has always been suspected to be a metallic oxide, from its great specific gravity, from its forming coloured salts, from its being precipitable by prussiate of potass, and from its muriate yielding oxymuriatic acid.

Lime.

Lime is of a white colour; it has no smell, but has an acrid penetrating taste, and it corrodes animal substances. Its specific gravity is 2.3. It is soluble in 680 times its weight of water.

Lime has been decomposed; its metallic base is called *calcium*, which has the lustre and colour of silver; if heated in atmospheric air, it burns with an intensely white light, and quicklime is the result.

The solution of lime is called *lime-water*, which is limpid, but has an acid taste, and turns vegetable blues to green. If lime-water be allowed to stand, a scum, called the cream of lime, forms on its surface, and if this be removed, another follows, till by this means the whole of the lime may be separated from the water If the lime be not skimmed, the cream, after having

acquired a certain thickness, precipitates, and falls to the bottom.

Pure lime, or calcareous earth, is never found native; but in combination with acids, particularly the carbonic, it exists in prodigious quantities. Marble, limestone, and chalk, are all carbonates of lime; gypsum is a sulphate of lime.

The operation called burning lime, consists in exposing marble, limestone, chalk, oyster-shells, or any other carbonate of lime, for some time to a white heat, by which means the carbonic acid and water contained in these substances is expelled; and the earth which has the peculiar characters assigned to lime, is left behind, in a mass which has little coherence, and is easily reduced to powder. It is usually called quicklime.

Newly prepared lime, absorbs water with extreme avidity; it will absorb one-fourth of its weight of that fluid, and still remain perfectly dry. If a sufficient quantity of water be poured upon it, lime falls into powder, some of the water is converted into vapour by the disengaged caloric of that part which unites with the lime This is called the slacking of lime: if the quantity slacked be considerable, and performed in a dark place, light will be observed as well as heat.

Lime with water forms a paste of but little cohesion; for common mortar it is mixed with rough sand to give it firmness; but the mortar for the outermost covering of indoor work, is mixed with hair, to give it cohesion without lessening its capability of receiving a smooth surface.

Lime absorbs carbonic acid gas as well as water from the atmosphere, and if not made into mortar before it has imbibed any considerable portion of it, the mortar is of little value. It is by the absorption of carbonic acid, that mortar acquires hardness, its lime being slowly converted again to the state of limestone, but the hardness will not be perfect unless undisturbed from its commencement; when this circumstance is observed, it soon acquires a moderate degree of hardness; but ages are probably required for it to attain its maximum. The silex or sand mixed with lime, operates by hastening its crystallization.

Lime, though infusible alone, promotes the fusion of all the other earths, and is used in melting iron ores; it serves as a flux to the alumine and silex which the ores of that metal contain.

Marl, which is of so much value in agriculture, consists of a mixture of lime and clay, and it is the calcareous part of its composition to which its value is owing; if the quantity of lime in it do not exceed 30 per cent. it is worthless. Every good soil contains a portion of carbonate of lime, which

materially assists in retaining the moisture necessary to active vegetation. Limestone containing much magnesia, is unfit to afford lime for the farmer's use; it may be known from good limestone by its being much longer in dissolving in acids.

Lime is used by the soap-manufacturer to render soda caustic, and therefore the more nearly it is in a caustic state itself, the less the quantity of it which will suffice. Hence it should be used as soon as possible after it has been burnt, or, if this be not done, it should be preserved in air-tight casks until required.

It enters into the composition of glass, which it renders less liable to attract moisture, and less brittle than it would otherwise be.

It is employed in the manufacture of glue, to prevent its becoming flexible by the absorption of moisture. It is also used by the tanner to facilitate the removal of the hair from skins.

Lime is used in refining sugar; it absorbs the acid which would prevent the sugar from perfectly crystallizing.

Strong lime-water may be advantageously employed to cleanse feathers from their animal oil, and render them fit for use. They should be steeped in it for some days.

Acids dissolve pure lime without effervescence, but heat is evolved during the solution. Water impregnated with carbonic acid, will dissolve a much larger quantity of it than before; and when deprived of this acid by exposure to the air, the lime it held in solution is precipitated. Hence the formation of stalactites and incrustations found in caverns.

The crystals of the solutions of lime in acids form what are called spars. The beautiful spar called fluor spar, or Derbyshire spar, is a fluate of lime, that is, a combination of lime and the fluoric acid.

Combined with muriatic acid, large quantities of lime are held in solution by the waters of the ocean.

Combined with sulphuric acid, lime forms gypsum; gypsum, when calcined by a moderate heat, is called plaster of Paris, which is of great utility to the marble-mason, for cementing and bedding stones; to the plasterer, for the ornamental parts of ceilings, as well as an ingredient in the finest mortar; and to the modeller, for multiplying busts, &c. Gypsum contains 30 parts of sulphuric acid, 32 earth, and 38 water.

Combined with phosphoric acid, lime forms the solid parts of the bones of all animals.

The best test to discover the presence of lime in any solution, is oxalic acid, which forms with it an insoluble precipitate.

The shells of testaceous animals consist chiefly of carbonate of lime cemented by a small portion of animal glue, while those of crustaceous animals always contain more or less of phosphate of lime, which approximates them to the nature of bone.

Barytes.

Barytes is of a grayish colour; it has a more caustic taste than lime, but has no smell; it changes the vegetable blues to green; forms a soap with oils, and combines with sulphur like the fixed alkalies. Its specific gravity is 4. When recently prepared, it absorbs water like lime, but more violently. Boiling water will dissolve half its weight of barytes, part of which will crystallize as the solution cools. The crystals are transparent and colourless. Cold water holds only one-twenty-fifth of barytes in solution.

Barytes has been decomposed by Sir H. Davy, who separated from it a peculiar metal which he called *barium*. Barium has the colour of silver, and sinks, if dropped into sulphuric acid; but like the bases of all the other earths which have been decomposed, it is obtained in too small quantities, and preserved in its metallic state with too much difficulty, to have its properties distinctly ascertained.

Barytes is generally found combined either with the sulphuric or carbonic acid; its sulphate is the most plentiful, being frequently met with in England, and generally it is common in copper mines; it was formerly called *ponderous spar;* the pure earth may be obtained from it in the following manner: Pulverize the sulphate of barytes, and calcine it in a crucible with one-eighth part of powdered charcoal; the crucible must be kept at a white heat for an hour, after which its contents must be thrown into water. The water acquires a yellow colour, and emits the smell of sulphuretted hydrogen; it must then be filtered, and muriatic acid poured in. A precipitate is obtained, which must be separated by filtration. The water which passes through the filter, holds muriate of barytes in solution. By adding carbonate of potass to the solution, the barytes is thrown down in combination with carbonic acid, which may be separated by a strong heat; or more easily by pouring nitric acid upon it, and then expelling the nitric acid by a gentle heat.

Barytic-water, like lime-water, absorbs carbonic acid from the air, until the whole of the earth is converted into carbonate and precipitated. This earth, and most of its salts, as well as its solution in water, are strong poisons, unless the quantity taken be extremely small.

Barytes has a greater affinity for sulphuric acid, even than the pure alkalies; it will therefore decompose sulphate of potass or sulphate of soda. Muriate of barytes is one of the best tests of the presence of sulphuric acid. This salt is likewise used in medicine for scrofulous complaints, though it is a hazardous remedy.

Barytes is distinguished from all the other earths by its being precipitated by muriate of potass, and by its giving a yellow tinge to flame.

It supplies an unchangeable and excellent white for painting in water-colours. This white is sold under the name of "Hume's permanent white," and possesses the peculiar advantage of being mixed with other colours without altering them.

Strontian.

The mineral from which this earth was first obtained, is found at the lead-mine of Strontian in Argyleshire. This mineral is the carbonate of strontian; in this state, or combined with other acids, particularly the sulphuric, strontian has been found in various other parts: its sulphate is found in Pennsylvania, and in the neighbourhood of Paris.

Pure strontian is of a grayish white colour; its taste is pungent and acrid, but less so than barytes. It dissolves in 100 parts of cold water, and its solution is not poisonous, boiling water dissolves it in much greater quantity, and the solution in cooling affords transparent crystals. It gives a purple tinge to flame, unless moisture be present, when the flame is a carmine red. Its specific gravity is 3.4.

Strontian changes vegetable blues to green; and when water is thrown upon it, it gives out heat like lime, and falls to powder. This earth has not been applied to any use, except in medicine. Dr. Pearson has prescribed it to correct acidity, instead of magnesia; it is not so liable as magnesia to act as an aperient.

Sir H. Davy has proved this earth to be a metallic oxide, as it yields oxygen when submitted to the means for decomposing the fixed alkalies. Its metallic base he has called *strontium;* it has nearly the same properties as that of barytes.

Pure strontian may be obtained by exposing the carbonate, mixed with charcoal powder, to a strong heat; or by powdering the carbonate, then dissolving it in nitric acid, and decomposing the nitrate by heat.

OF STONES OR FOSSILS.

The whole of the rocks, stones, and mould, which form so large a portion of our globe, so far as they have yet been examined, appear, as before observed, to have for their bases one or more of the nine preceding earths, in different states of combination. To the eye, and in properties apparent to the senses, the variety which surrounds us seems infinite; we know very little of the processes which nature has employed to produce this variety; but the more skilful we become in chemical analysis, the more clearly we perceive that the elements of all things are few in number. We shall particularize the leading varieties of fossils.

Aluminous Fossils.

Aluminous or argillaceous stones are very abundant; with some rare exceptions, they are all soft enough to be cut with a knife, and they do not, like aluminous earths, fall to powder by mere immersion in water.

Corundum.

Corundum, or adamantine spar, is brought from China and the East Indies. Its specific gravity is from 3.9 to 4.1. Its hardness is so great, that it cuts glass as easily as the diamond, and marks rock crystal; it is even sometimes used for polishing the diamond, and frequently for cutting and polishing other gems, instead of diamond dust. The Chinese corundum is gray, the Indian white; neither is transparent. A specimen of this stone, analyzed by Chenevix, yielded 86.50 parts of alumine, 5.25 of silver, 6.50 of iron.

The various stones known under the name of ruby, sapphire, &c. are nearly of the same nature as the corundum; they consist chiefly of alumine, and are sometimes considered only as varieties of the corundum. Their greater or less excellence of colour, and their being more or less homogeneous and hard, occasions the important differences in the value put upon them.

Hornstone, or Hornblende.

Hornstone, or hornblende, has a close grain, generally a striated or lamellated texture, and a black or greenish gray

colour. It is pulverized with difficulty, not from its hardness, which is not such as to prevent its being cut with a knife, but from a certain tenacity, which admits of its being flattened in some degree under the hammer like horn, and from this property it derives its name. The specific gravity of different specimens varies from 2.66 to 3.88. When breathed upon, or moistened with hot water, it has a strong earthy smell, and is partially soluble in acids. It may be fused into glass by an intense heat. The black hornblende is sometimes so soft as to be scratched with the nail.

A specimen of this stone, analyzed by Kirwan, consisted of silex 37, alumine 22, carbonate of magnesia 16, carbonate of lime 2, and oxide of iron 23.

Rocks consisting principally of hornblende and black iron clay, are called by Werner trap-rocks, of which he distinguishes several species: porphyry is one of them, it encloses crystals of quartz, feldspar, &c. imbedded in hornstone or some other matrix; when clay is the matrix, the porphyry is considered as of more recent formation than the other.

Basaltes.

This fossil is commonly found in forms which constitute one of the most wonderful phenomena of nature. The giant's causeway in Ireland, which consists of basaltes, is an immense aggregation of columns, for the most part hexagonal. These columns are composed of short masses which fit each other with the greatest nicety. The surfaces are not flat, but one convex and the other concave. They are sometimes united by a strong cement, but even when this is not the case, the exactness with which they fit each other is such that water cannot penetrate at the juncture. The basaltic phenomena of the Hebrides are on a still grander scale than those of Ireland. The columns are of all heights up to two hundred and fifty feet.

Basaltes is generally of a dark gray, or deep greenish black colour, and a ferruginous appearance externally. Dr. Kennedy obtained from the basaltes of Staffa, silex 48, alumine 16, oxide of iron 16, lime 9, soda 4, muriatic acid 1, water and volatile parts 6. In some specimens the proportion of alumine is greater.

Basaltes may be fused into a black glass, which is opake, and extremely light. Equal parts of basaltes, soda, and sand, furnished Chaptal with a glass of an olive green, which united solidity and lightness. The hardest basaltes should be used, but it is not managed without difficulty.

Mica.

Mica has a shining appearance, a scaly texture, a slight degree of elasticity, and is soft to the touch, but not greasy, which distinguishes it from talc. Its specific gravity is from 2.5 to 3.0.

Mica is sometimes found colourless, but it is generally either white or yellow, though sometimes greenish, red, brown, or of other colours. Colourless mica is infusible, but the coloured may be fused.

Colourless mica afforded Kirwan 28 parts of alumine, 38 silex, 20 magnesia, 14 oxide of iron.

White and yellow mica are reduced to powder, and sold under the name of gold and silver sand, which is used for drying writing ink.

Mica is generally mixed with feldspar, quartz, and schorl, and generally forms a part of primitive rocks.

Schistus.

This is a general name for all stones which can be split into plates or laminæ, but more particularly the argillaceous stones answering to this description. It therefore includes slates, hones, and flag-stone.

Slate is distinguished by the very thin plates into which it may be divided, and which property renders it valuable for tablets and as a roofing material; it will receive a smooth surface, and some specimens take a slight polish; it is of various colours, but generally of different shades of blue; alumine, silex, carbonate of magnesia, lime, and iron, enter into its composition, in various proportions in different specimens. The stones used as hones or whet-stones, though so different in their qualities for the use to which they are applied, differ not much from slate in their chemical composition.

Flagstone consists chiefly of clay and silex, tinged with the yellow or red oxide of iron.

All the schisti are permeable to water.

Zeolites.

The stones called zeolites, are generally of a semi-transparent white, but from metallic admixtures, they assume all colours. They are distinguished in part by the property of forming a jelly with acids. Their specific gravity is from 2.1 to 3.15. They may be fused with carbonate of soda, and, though not so easily, with borate of soda. Pelletier obtained from the white zeolite of Ferroe, 50 parts of silex, 20 alumine, 8 lime, and 22 water.

Siliceous Fossils.

Siliceous fossils strike fire with steel; and they are generally susceptible of a fine polish; a great number of gems belong to this class.

Quartz, or Rock Crystal.

Quartz, or rock crystal, is extremely abundant; it consists almost entirely of silex; this fossil, when coloured, is called *quartz;* but when perfectly clear, it is called *rock crystal.* Rock crystal afforded Bergman 93 parts silex, alumine 6, and lime 1. Its specific gravity is about 2.6.

Quartz is coloured by a very small metallic admixture; the most usual colours are red, yellow, green, violet, and blue; coloured quartz forms false gems, which are deprived of their colours by heat.

A species of stone called *elastic quartz*, is found in the diamond mines of the Brazils. It is composed of flat, longish scales, all interwoven in one direction, and perfectly pellucid. It has nearly the appearance of Turkey-hone, but contains as much silex as common quartz, and easily cuts glass.

Feldspar.

This stone exists alone or with quartz, in many combinations; it has been also called *scintillating spar, fusible spar,* and *rhombic quartz.* Its texture, though close, is lamellated, and it breaks like spar. Its specific gravity is from 2.4 to 2.6, and though not so hard as quartz, it is hard enough to give fire with steel. It is generally opake, and its most common colours are white, red, yellow, brown, green, and violet. The figure of its crystals is generally irregular, but often rhombic, cubic, or parallelopipedal. The crystals decrepitate in the fire, and may be fused into whitish glass. It never constitutes veins or strata, but is found in sand or clay, or imbedded in granite and other stones.

One hundred parts of the white feldspar contain about 67 of silex, 14 of alumine, 11 of barytes, and 8 of magnesia.

Flints.

Common flint is in general use for striking fire with steel, and is therefore well known; it varies in colour from a light brown almost to black; it is semi-transparent at the edges, or

where very thin. Its specific gravity is 2.65. It is commonly found in nodules in beds of chalk and sand. By long exposure to the atmosphere it is decomposed. It contains 80 per cent. of silex, 18 of alumine, and 2 of lime.

Petrosilex or chert, differs from common flint principally in being less hard, in having a coarser texture, and in being found in large masses. It occurs most frequently in beds of limestone. It is made into grindstones for pulverizing hard substances. It becomes white in the fire like common flint; but it may be fused alone, which common flint cannot.

Jasper is a general name for flints which are opake, and the texture of which resembles dry clay. They are found of a great variety of colours, and are often very hard. They are fusible with borax more readily than other flints. Alone, fire only hardens them. They generally contain from 50 to 60 per cent. of silex.

Small roundish flints, united by any kind of cement, are called *pudding-stones;* but when the flints are angular, the stone is called *breccias*. Of the coarsest stones of this description, are made the stones for grinding grain.

Agates.

Agates are a finer kind of flint, and there are many varieties of them. They all resist the file, and take a beautiful polish.

The stone distinguished simply by the name of *agate*, has a vitreous appearance, and is semi-transparent. The purest is white, but various shades of yellow and other colours distinguish its varieties; besides the distinctions occasioned by clouds, spots, and the appearance of vegetation. The specific gravity of agates is about 2.64.

The *opal* is one of the most beautiful of the agates; it is semi-transparent, and of a milky whiteness; but it changes its colour, and appears blue, red, or green, according to the position in which it is held.

The *chalcedony* is of a milky whiteness, like the opal, from which it differs only in not possessing the changeableness of colour. It has been found in the mines of Cornwall, in beautiful stalactites. It contains generally about 84 per cent. of silex.

The *carnelion* is an agate nearly transparent, of different shades of brownish red or flesh colour. Its specific gravity is about 2.6. The yellowish red or orange carnelions are the hardest and most esteemed. Ignition deprives this stone of its colour and transparency.

The *garnet*, when transparent, is reckoned among the gems. Its colour is usually bluish or yellowish red; its texture lamellated. It is harder than rock crystal. Its specific gravity is from 3.6 to 4.188. Achard obtained from 100 parts of it, silex 48.3, alumine 30, lime 11.6, iron 10.

Lapis Lazuli.

Lapis lazuli is entirely opake; of a fine blue colour, sometimes mixed with white, yellow, and streaks and specks of different colours; the yellow arises from the admixture of pyrites. It has a fine texture, and takes an excellent polish It is hard enough to scratch glass. Its specific gravity is 2.7. By a strong fire it may be fused without addition into a whitish glass. According to Klaproth, it contains of silex 46 parts, alumine 14.5, carbonate of lime 28, sulphate of lime 6.5, oxide of iron 3, water 2. It is from this stone that ultramarine, the most beautiful of all blues for painting, is prepared.

Schorl.

Schorl has a sparry or semi-vitrified appearance, and filamentous texture; it is fusible at a moderate heat; its specific gravity is generally from 3 to 3.6, but when containing much iron, it is 4. In hardness it sometimes equals crystal. It exhibits great variety of colour and form, and is found both transparent and opake.

Transparent Schorl is always crystallized in some polygonal form; its colours are red, reddish brown, greenish, yellowish brown, or violet.

Opake schorl is often soft enough to be cut with a knife; it is met with of all colours, but generally either white, black, green, or violet; the filaments are conjoined and parallel, or diverge as from a common centre.

Schorl loses its colour in the fire, and one-thirtieth of its weight; it first becomes of a grayish white, but a stronger heat converts the violet into a black enamel; the white forms a white enamel.

The white schorl of the Pyrenean mountains afforded Chaptal, of silex 55 parts, alumine 22, magnesia 13, lime 7. In other specimens, the quantity of silex is rather more, and that of alumine much less.

Granite.

Granite consists of feldspar, quartz, and mica, with slight admixtures of other stones, particularly schorl and hornblende. The feldspar is the predominating substance, and it is chiefly

to its difference of colour, that the colour of the granite is owing. The proportion of mica is generally inconsiderable. The granite consisting of quartz, feldspar, and mica, is the hardest, and is supposed to be the oldest.

The red granites consist commonly of white quartz, red feldspar, and gray mica. The gray granite, of white quartz, gray or violet feldspar, and black mica. Black granites commonly contain schorl instead of feldspar, and the green is produced by green quartz. Granite is the most abundant fossil of the globe.

Magnesian Fossils.

The fossils which derive their character from magnesia, though they do not all contain a great proportion of this earth, are distinguished by their being greasy to the touch; and they have neither the hardness nor infusibility of siliceous fossils.

Talc.

Talc has a laminated texture, and a metallic lustre; it is of a white, gray, yellow, or greenish colour; it is soft and soapy to the touch, which distinguishes it from mica; in thin leaves it is transparent. It may easily be scratched with the nail. Its specific gravity is 2.7.

Muscovy talc is obtained in large leaves, which are elastic and flexible. In the quarries of Vitim, in Siberia, talc has been raised in plates of eight feet square.

In the fire, talc becomes more brittle and whiter; but it is infusible by the blow-pipe, and can scarcely be fused by the addition of alkali. The borate of soda, and the phosphate of urine, fuse it with a slight effervescence.

Talc contains generally about 50 parts of silex, 44 magnesia, and 6 of alumine.

Steatites.

Steatites, or soap-rock, is generally of a greenish colour, greasy to the touch, and easily scraped with the nail. Its specific gravity is from 2.4 to 2.7.

Steatites becomes harder and whiter in the fire, and in its hardened state will take as fine a polish as the agate. It is not fusible alone, but may be fused by the addition of borate of soda. A specimen of steatites from Cornwall afforded Klaproth, of silex 48 parts, magnesia 20.5, alumine 14, oxide of iron 1, water 15.5.

Serpentine.

Different specimens of serpentine vary considerably from each other. In texture, it is either compact, granulated, scaly, lamellated, or fibrous; and in colour, white, green, brown, red, yellow, light blue, black, and often streaked or spotted with different colours. It is distinguished from steatites by its greater hardness; its taking an excellent polish, and its being less greasy to the touch. Its specific gravity is from 2.4 to 2.65. In thin pieces, it is sometimes semi-transparent. It melts in a violent heat, but is hardened by a less degree of heat than is required for its fusion.

A serpentine analyzed by Knock, afforded of silex 45 parts, magnesia 33, magnetic iron 14, carbonate of lime 6.25, alumine 25, with a little muriate of magnesia and water. Sometimes this stone contains no alumine.

Asbestos.

Asbestos has a fibrous texture, and is slightly flexible; its colour is usually greenish, and it is rough to the touch. Its specific gravity is from 2.5 to 2.8. Fire renders it whiter and more brittle, but it does not enter into fusion by the blowpipe, though it shews some symptoms of it; when mixed with iron, which it frequently is, it melts into a semi-transparent glass. Bergman found different specimens of asbestos to contain from 53 to 74 parts silex, from 12 to 28 of carbonate of magnesia, from 7 to 14 of carbonate of lime, from 2 to 6 of alumine, and from 1 to 10 of iron.

The *amianthus* and *mountain cork* differ but little from asbestos. The fibres of amianthus are softer, longer, and more flexible, and more easily separated than those of asbestos. The fibres are sometimes eight inches long. Amianthus contains less silex than asbestos, and sometimes contains about 6 per cent. of sulphate of barytes. It is more fusible, but less acted upon by acids than asbestos; it is sometimes called *mountain flax*.

Mountain cork receives its name from its having some resemblance to cork; it is of a white, yellowish gray, or brown colour, without lustre or transparency. Its specific gravity is from 0.68 to 0.99. It contains of silex 56 parts, carbonate of magnesia 26, alumine 2, carbonate of lime 13, and oxide of iron 3.

Calcareous Fossils.

Calcareous fossils are generally harder than the magnesian, but not so hard as the siliceous; none of them strike fire with steel; some of them imbibe water, and crumble by exposure to frost; others become harder by the same exposure; when crystallized, in combination with carbonic acid, they generally possess the property of double refraction, that is, objects seen through them, as the printing of a book, appear double.

Crystallized calcareous Stones.—(Carbonates.)

Calcareous spars are soft, laminated, and distinguished from other spars by their effervescence with acids. Their figures are various, but in general they are rhomboidal, or approach nearly to that form: they sometimes present a pyramidical form, and are then called dogtooth spars. Some are transparent, others opake; and both these classes are found coloured and colourless. Their specific gravity is about 2.7. They contain from 30 to 36 parts of carbonic acid, and from 53 to 55 of lime; the rest is water.

Crystallized carbonates form but a very small proportion of the calcareous matter of the globe.

Marble.

Calcareous stones which take a fine polish, and have one or more agreeable colours, are called *marble*. White marble is the purest; it consists almost entirely of carbonate of lime. The colouring principle of marbles is generally iron The carbonate of lime, when of a dull colour, is called *limestone*.

Limestone is the most abundant of the calcareous stones; its strata are often immensely extensive.

Stalactites.

Stalactites, or petrifactions, are deposited by water, charged with calcareous matter in a state of minute division. They are very commonly pendent from the roofs of caverns in limestone countries. They are generally coloured by iron, and as they are formed by layers applied externally, if cut in a direction perpendicular to the layers, they exhibit rings of different shades, according to the matters which the water held in solution when each layer was deposited. Their specific gravity

is 2.7. They contain generally about 64 parts of lime, 34 carbonic acid, and 2 of water.

The calcareous depositions on the floors of caverns, are called *stalagmites*.

Gypsum.

Gypsum, alabaster, selenite, plaster-stone, or, as it is now called, sulphate of lime, forms very extensive strata, in many parts of the world. Its specific gravity is 2.3. It consists of 32 parts of lime, 46 sulphuric acid, and 22 of water. It loses about 20 per cent. by calcination. The whitest gypsum is the purest, and the most esteemed. When coloured, it is generally owing to the presence of iron. Gypsum exhibits a semi-crystallized appearance, almost like stalactites.

Fluor Spar.

Fluor spar, or fluate of lime, exhibits, like other crystallized stones of the calcareous kind, a lamellated texture, but it has not like them the property of double refraction. Its colours are exceedingly varied, and in general beautiful, and it receives a high polish. Its specific gravity is 3.1. It contains, according to Scheele, of lime 57 parts, fluoric acid 16, and water 27.

Volcanic Productions.

The productions of volcanoes are comprehended under the general name of *lavas*, which are by no means uniform in their appearance or composition. Lava has in general a dark and almost black colour, with a semi-vitreous or glistening fracture. It is porous, light, easily broken, and mostly attractable by the magnet. It may be fused into glass without much difficultly.

One of the volcanic products best known, is called *pumice-stone*. It is of a light gray colour; its fracture exhibits a filamentous appearance, and a silky lustre. It is generally used for giving a smooth surface to metals, but it is said to furnish an excellent glaze for pottery.

The pumice-stone of Lipari afforded Klaproth, of silex 77.5 parts, alumine 17.5, oxide of iron with a little manganese 1.75, soda and potass 3.

OF SALTS.

The compound formed by the combination of an acid with an alkali, an earth, or a metallic oxide, is called a *salt*.

The term *neutral salt* was formerly given to all combinations of acids and alkalies, but the epithet *neutral* is now restricted to those salts in which the acid and the alkali completely saturate each other, and in which therefore the peculiar properties of neither can be detected.

When a salt contains an excess of acid, its state is indicated by the addition of the word *super;* and sometimes by the term *acidulous;* but the latter mode of denoting the distinction, is yielding to the former.

When the salt contains an excess of alkali, the preposition *sub* is prefixed to its name, or the epithet *alkalinous;* but the first-mentioned addition is the most general and appropriate.

The *base* or *radical* of a salt, is the alkali, the earth, or metallic oxide, which is combined with the acid.

Agreeably to the principles adopted in framing the new chemical nomenclature, every salt receives a compound name, denoting its base, and the acid which enters into its composition. Thus the chemical name of common salt is *muriate of soda*, as it is a combination of the muriatic acid and soda. Saltpetre is called *nitrate of potass*, because it is a combination of potass and nitric acid. Glauber's salt is called *sulphate of soda*, as it is a combination of soda with the sulphuric acid; and the salts formed by all the other acids, are reduced to the same form of expression.

When an acid is combined with two bases, the compound is called a *triple salt*, and both the bases are expressed, thus we have the *tartrate of potass and soda*. A single base combined with two acids, is denoted with equal precision; thus we have the *nitro-muriate of tin*.

When the epithet which distinguishes the acid of a salt, terminates in *ate*, it signifies that the epithet of the acid itself terminates in *ic;* thus the sulphuric acid forms *sulphates:* when the epithet of the salt terminates in *ite*, that of the acid itself terminates in *ous;* thus the sulphurous acid forms *sulphites*. Most of the salts ending in *ous*, attract oxygen from the atmosphere, and are converted into the former kind.

The salts form a very numerous class of bodies. Fourcroy reckons that there are 134 species, and the number belonging

to each species is often considerable. There can scarcely be less than 2000 distinct salts; but we shall only notice some of the most useful.

Sulphates.

The sulphates are in general crystallizable, have some taste, but no smell; are precipitated by solution of barytes, and afford sulphurets when heated red-hot with charcoal. They are numerous, as the sulphuric acid combines with all the alkalies, and nearly all the earths and metallic oxides.

Sulphate of Alumine.

Sulphate of alumine, is formed by dissolving alumine in sulphuric acid. It has an astringent taste, is very soluble in water, and crystallizes in thin plates, which have very little consistence. It generally contains an excess of acid.

We should have omitted the mention of this salt, but to distinguish it from the following one, to which the same name is apt to be given.

Sulphate of Alumine and Potass, or Ammonia.

This salt is the common alum of commerce. It has an austere, sweetish, astringent taste, and always reddens tincture of litmus. Seventy-five parts of boiling water dissolve 100 of alum, at the temperature of 60°; it is soluble in from 10 to 15 times its weight of cold water, the purest alum having the least degree of solubility. Its crystals are large. By exposure to the air it slightly effloresces. Its specific gravity is 1.7.

According to Vanquelin, alum contains of alumine 10.50, sulphuric acid 30.52, potass 10.40, water 48.58.

Two kinds of alum are found in commerce, the common and roch-alum. The latter has a reddish tinge, from an admixture of rose-coloured earth; it is also the most esteemed, and sold at the greatest price, though the cause of its superiority is not well known.

The uses of alum are very extensive. In dyeing it is of considerable importance for fixing several vegetable colours. It is used in the tanning of leather, to give firmness to skins, after they have been in the lime-pits; and in the manufacture of candles, to give consistence to the tallow. The blocks used by the calico-printers are rubbed with burnt alum, to remove any greasiness which might prevent the colour from adhering.

Alum is also used in the manufacture of writing papers, to make the paper bear ink better.

Alum is prepared in France by the artificial combination of its component parts; but in Great Britain it is obtained from a kind of slate called *alum-slate*, which is plentiful on the north-east coast of Yorkshire, and near Glasgow; about 100 tons of the slate only afford 10 tons of alum.

Ammonia will contribute to the formation of alum as well as potass.

Sulphate of Soda.

The sulphate of soda has a strongly saline and bitter taste; its crystals are transparent, but they effloresce and fall into a white powder in the air; it is soluble in rather less than three times its weight of water at the temperature of 60°, and in $\frac{8}{10}$ths of its weight of boiling water. It is principally used in medicine, as a purgative, under the name of Glauber's salts. According to Kirwan, it contains of acid 22 parts, soda 17, water 61.

Green Sulphate of Iron.

This salt is the copperas or green vitriol of commerce. Its crystals are of a beautiful light green; it has a sharp astringent taste, and is poisonous. It is soluble in six times its weight of water at the temperature of 60°, and in three-fourths of its weight of boiling water. It is insoluble in alcohol. According to Bergman it contains of acid 39 parts, green oxide of iron 23, and water 38. It is efflorescent.

Green sulphate of iron is obtained by the decomposition of pyrites or native sulphuret of iron; and this decomposition is effected by simple exposure to air and moisture. This salt is much used in dyeing blacks; in preparing writing ink; and by bookbinders for staining black the skins which have been tanned with oak bark.

Red Sulphate of Iron.

If nitric acid be distilled off the green sulphate of iron, or the solution of this salt be exposed to the air, the *red sulphate of iron* is obtained. It is deliquescent, incrystallizable, and soluble in alcohol. Proust observes that it alone forms prussian blue with prussic acid, and strikes a black colour with gallic acid; and therefore, when these effects are attained by operating with the green sulphate, the latter salt has derived from the atmosphere, or some other source, the additional quantity of oxygen necessary to convert its iron to the state of red oxide.

Sulphate of Copper.

The crystals of this salt, which was formerly called *blue vitriol*, are a fine deep blue. It has a strong styptic taste; is soluble in four times its weight of water, and effloresces in the air. Its specific gravity is 2.2. It is generally obtained by evaporating the waters of copper-mines.

The sulphate of copper is employed as a caustic, to remove the flesh of fungous ulcers. It is dangerous to administer it internally.

Sulphites.

Sulphites have a disagreeable, sulphurous taste. If exposed to the fire, they yield sulphur, and are converted into sulphates, and even by mere exposure to the atmosphere, the same change is produced. They are also decomposed by the nitric, muriatic, and other acids which do not affect sulphates. They are mostly formed artificially.

The principal sulphites are those of potass, soda, ammonia, alumine, magnesia, and barytes; none of these have been applied to purposes of any importance.

Nitrates.

The nitrates are soluble in water, and crystallizable; they deflagrate violently when heated to redness with charcoal, or other combustibles; sulphuric acid disengages from them a white vapour of nitric acid. By heat they are decomposed, and yield at first a considerable quantity of oxygen gas.

Nitrate of Potass.

Nitrate of potass, saltpetre, or nitre, is the best known and most important of all the nitrates. Its taste is sharp, bitterish, and cooling. It is very brittle. Its specific gravity is 1.9. It is soluble in seven times its weight of cold water, and in rather less than its weight of boiling water. When mixed with one-third of its weight of charcoal, and thrown into a red-hot crucible, or when charcoal is thrown upon red-hot nitre, the combustion that ensues is exceedingly vivid and beautiful. The residuum is carbonate of potass. The combustion is still more violent, when phosphorus is used instead of charcoal.

According to Kirwan, nitre contains of acid 41.2 parts, potass 46.15, water 12.65. All the nitric acid employed in the arts, is furnished by the decomposition of this salt. The sulphuric acid is employed to effect the decomposition. Considerable quantities of nitre are also used in obtaining sulphuric acid, as it supplies the oxygen for the combustion of sulphur in close chambers. The manufacture of gunpowder also requires an immense quantity.

A considerable part of the nitrate of potass consumed in Europe, is furnished by the East Indies, where the soil, being impregnated with it, yields it by lixiviation and evaporation. At Apulia near Naples, also, there is a natural nitre-bed, in which the earth contains 40 per cent. of nitre. In Germany, France, and Switzerland, artificial nitre-beds are formed, by suffering animal and vegetable matters to putrefy in combination with calcareous and other earths. A soil of this kind attracts the nitric acid from the atmosphere. Old mortar furnishes a very proper calcareous earth for a nitre-bed.

Nitrate of Soda.

This salt was formerly called *cubic nitre*, from its crystallizing in rhombs. It is somewhat more bitter than the nitrate of potass, rather more soluble in cold water, but much less soluble in hot water. It is not of any important use, though Proust observes, that when made into gunpowder, it burns longer than common nitre, and might therefore be economically adopted for fire-works.

Nitrate of Ammonia.

Nitrate of ammonia has a sharp, acrid, and somewhat urinous taste; it deliquesces in the air, and is soluble in about half its weight of boiling water. The only use made of it is to furnish nitrous oxide.

MURIATES.

Though the muriates are the most volatile of all salts, they are at the same time the least decomposable; they may be melted and volatilized without undergoing decomposition. They effervesce with sulphuric acid, and white acrid fumes of muriatic acid are disengaged; when acted upon by nitric acid, oxymuriatic gas is disengaged.

Muriate of Soda.

Muriate of soda, or common salt, is too well known to require any description. It is the only substance to which the term salt was formerly applied. Besides the immense quantities of it held in solution by sea-water, it exists in prodigious masses in the state of rock-salt. Its specific gravity is 2.12; and it is soluble in rather less than three times its weight of water. When pure, it is not affected by the air; but common salt is deliquescent, from the magnesia and other impurities which it contains.

Muriate of soda contains of acid 44 parts, soda 50, and of water 6.

Muriate of Potass.

This salt was formerly called *febrifuge salt of Sylvius*, and *regenerated sea salt*. It has a disagreeable, bitter taste; its specific gravity is 1.8; it is soluble in three times its weight of cold water, and twice its weight of boiling water. When heated, it first decrepitates, then melts, and at last is volatilized without decomposition. According to Kirwan, it contains of acid 36 parts, potass 46, and water 18.

Muriate of Ammonia.

Muriate of ammonia, or sal ammoniac, has an acrid, urinous taste, an opake white colour, and a specific gravity of 1.4. It dissolves in three times its weight of cold water. It contains, according to Kirwan, 35 parts of acid, 30 of ammonia, and 45 of water.

Muriate of ammonia is employed for brightening some colours in dyeing; also for preserving the surfaces of metals from oxidation in tinning; in medicine it forms an excellent diaphoretic and febrifuge, and has been advantageously applied externally as a lotion for indolent tumors.

Hyper-oxymuriate of Potass.

If a solution of potass be saturated with oxymuriatic acid gas, and then evaporated in the dark, the first crystals formed are those of common muriate of potass; when these are separated, and the solution allowed to cool, the crystals of hyper-oxymuriate of potass are obtained. These crystals have a silvery lustre, and are insipid and cool to the taste. They are soluble in 17 parts of cold water, and 2½ parts of boiling water.

The hyper-oxymuriate of potass, when mixed with charcoal and other combustibles, and heated, detonates with extreme

violence. It also explodes when triturated in a mortar, or when struck with a hammer, if a small quantity of it is laid upon an anvil.

This salt consists of hyper-oxymuriatic acid 58 parts, potass 39, water 3. The oxygen is about equal to the salt in weight. It was called simply oxymuriate of potass, till Chenevix proved that the acid which enters into its composition is in the highest state of oxygenizement. He endeavoured to obtain this acid separately, but the retort containing the salt was reduced almost to powder by a violent explosion. The hyper-oxymuriatic acid has therefore never been exhibited separately.

Carbonates

Carbonates effervesce and yield carbonic acid, when sulphuric or nitric acid is poured upon them; all the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble, unless the acid be in excess.

Sub-carbonate of Potass.

The potass of commerce is always in the state of a sub-carbonate; the carbonic acid considerably weakens its alkaline properties, yet it will still change vegetable colours to green, and combined with oils, will form an imperfect soap.

Sub-carbonate of Soda.

The soda of commerce is in the state of a sub-carbonate; but its carbonic acid deprives it of more of its alkaline properties than it does potass; for making glass it is used in the state of a sub-carbonate, because the heat it is exposed to, drives off the carbonic acid; but to form soap it must be rendered caustic, which is effected by quicklime.

Carbonate of Lime.

Carbonic acid has the power of completely neutralizing the alkaline properties of lime, which it reduces to a state in which it is nearly tasteless. Under the name of chalk, marble, and limestone, we have already noticed this compound.

Fluates.

The fluates are not decomposed by heat, nor altered by combustibles; when sulphuric acid is poured upon them, they

yield acrid vapours of fluoric acid, which corrodes glass. When reduced to powder, and heated, but not made red-hot, some of them become phosphorescent.

The principal fluoric salts are, the fluates of lime, of soda, of potass, of ammonia, of barytes, of alumine, of silex, and of strontian; but this acid forms fluates with mercury, copper, tin, iron, nickel, and several other metals. The whole of the fluates are factitious salts, except those of lime and alumine.

Fluate of Lime.

Fluate of lime is well known under the name of Derbyshire spar, or Blue John. It is tasteless, and nearly insoluble in water. It is not altered by the air. Its specific gravity is 3.1. When powdered, and heated upon a shovel, it emits a violet-coloured light, but this ceases if it be made red-hot. It is fused by a strong heat, and is occasionally used as a flux. It exists in the enamel of the human teeth.

Fluate of Silex.

The fluoric acid gas will dissolve silex, and still retain its aërial form, but the silex is afterwards deposited in crystals.

Borates.

The borates are all fusible into glass, and assist the fusion of other bodies, particularly metals, and metallic oxides; with the metallic oxides, they form glass of different colours.

The principal salts of this class, are the sub-borate of soda, the borate of potass, of lime, of magnesia, and of alumine.

Sub-borate of Soda.

This is the only borate of any importance. It is dug out of wells in the kingdom of Thibet, and comes to us from the East Indies. It is then in a state of impurity, and is called *tincal;* when purified, it receives the name of *borax*. It is in whitish crystals, has a styptic and alkaline taste, and converts vegetable blues to green. It is soluble in twenty times its weight of cold water, and six times its weight of boiling water. When melted into glass, it is transparent, and still soluble in water. When two pieces of borax are struck together in the dark, a flash of light is emitted. Its specific gravity is 1.740. It slightly effloresces in the air.

According to Bergman, this salt consists of 39 parts of boracic acid, 17 of soda, and 44 of water. It is much used as a flux in soldering metals with the hard solders.

Acetates.

The acetic salts are distinguished by their great solubility in water; by the decomposition of the acid when the solution is exposed to the air; by their being decomposed by heat, and by their yielding acetic acid when mixed with sulphuric acid, and distilled.

The principal acetates are those of potass, of soda, of ammonia, of magnesia, of barytes, of lead, and of copper.

Acetate of Potass.

This salt has been long known, and has been distinguished by almost a dozen different names: of which one was *secret foliated earth of tartar*. It has a sharp warm taste; its crystals are white, and in the form of thin plates. It is soluble in alcohol, in ten times its weight of water, and is deliquescent. It is used in medicine.

Acetate of Ammonia.

This salt tastes like a mixture of sugar and nitre. It is extremely volatile, and cannot be crystallized, except by an extremely slow evaporation. Its crystals are long and slender, and of a pearl-white colour. It is deliquescent. Its solution has been long used medicinally, under the name of *spirits of Mindererus.*

Acetate of Lead.

This salt is formed by the solution of the white oxide of lead in the acetic acid. It has a sweet, and somewhat astringent taste, and is sparingly soluble in water. It becomes yellow by exposure to the air. Like all other preparations of lead, it is a strong poison; but in doses of a very few grains, it has been administered with evident advantage in desperate cases of internal hemorrhage; its solution in water is used externally as an embrocation. Heat decomposes it.

Acetate of Copper.

Acetate of copper has a disagreeable, coppery taste; a fine deep green colour, some degree of unctuosity, is efflorescent, and is soluble in water and alcohol. It is used in dyeing black, and a small quantity of it in writing-ink is an improvement. It is also much used in painting. In chemistry it is distilled for the acetic acid it affords.

TARTRATES.

The tartrates are decomposed by a red heat. The earthy tartrates are less soluble than the alkaline, but they are all capable of combining with another base, and forming triple salts.

The principal tartrates are those of potass, of potass and soda, of potass and ammonia, of lime, of strontian, and of potass and antimony.

Super-Tartrate of Potass,

Is the cream of tartar of the shops. It has a strong, but not disagreeable acid taste; is soluble in thirty times its weight of boiling water, and is not altered by exposure to the air. According to Bergman, it contains 23 parts of potass, and 77 of acid. It is used in medicine as a mild aperient. It is also useful in dyeing.

Tartrate of Potass and Soda.

This triple salt is sold by the druggists under the name of *Rochelle salts.* It has a strongly saline and bitter taste; is efflorescent, and is soluble in about four times its weight of cold water. It is a mild cathartic.

Tartrate of Potass and Antimony.

The crystals of this triple salt are of a white colour, and transparent. It is soluble in 60 parts of cold water. It is formed by precipitating the muriate of antimony with a hot solution of potass in distilled water. The precipitate being well washed and dried, nine drachms are to be boiled in five pounds of water, with two ounces and a half of super-tartrate of potass, finely powdered, till the powders are dissolved. The solution must then be strained, evaporated to a pellicle, and left to crystallize. In doses of from two to four grains, this is the best and most powerful emetic known.

PHOSPHATES.

The phosphates are capable of vitrification; are partially decomposed by sulphuric acid; are phosphorescent at a high temperature; are soluble in nitric acid, without effervescence; and may be precipitated from their solutions by lime-water.

The principal phosphates are those of potass, of soda, of ammonia, of soda and ammonia, of lime, of alumine, and of magnesia.

Phosphate of Soda.

The phosphate of soda has nearly the same taste as common salt; it is soluble in water, and efflorescent. As a cathartic, it is equivalent to Glauber and Rochelle salts, and as its taste is much pleasanter, it has been used instead of those well-known medicines. It may be administered by dissolving it in weak broth, to which it serves as an agreeable seasoning. Dr. Pearson first prepared and introduced it. It is used in the arts as a flux instead of borax.

Phosphate of Soda and Ammonia.

This compound, which was formerly called *microcomic salt*, is much used as a flux in assays with the blowpipe. It may be obtained from human urine by evaporation.

Phosphate of Lime.

Phosphate of lime is white, tasteless, and insoluble in water. As it forms the bases of bones, it has been sometimes called the *earth of bones*. It exists in milk, and some other animal products, also in wheat. In Spain it has been found abundantly in the fossil state.

PRUSSIATES.

The singular affinities of some of the prussiates render them interesting to the chemist; the simple prussiates are, however, little regarded, because destitute of permanency, being decomposed merely by exposure to the air, unless united with a metallic oxide. The prussic acid does not appear capable of saturating an alkali; and the weakest acid known is capable of decomposing the prussiates of the earths and alkalies.

The most important of the simple prussiates is that of iron; and of the triple prussiates those of potass, soda, lime, and ammonia with iron.

Prussiate of Iron.

The prussiate of iron, or prussian blue, is, according to Proust, a combination of the prussic acid and red oxide of iron. With the green oxide, the prussic acid forms a white compound, which, however, becomes gradually blue by exposure to the atmosphere, from the absorption of oxygen. It is a fine deep

blue, and valuable as a pigment; it is insoluble in water, very sparingly soluble in acids, and not affected by exposure to the air. It is composed of equal parts of the acid and oxide. If exposed to a strong heat, the acid is destroyed, and the residuum is simply oxide of iron.

If the blue prussiate of iron be deprived of part of its acid, by digesting it with alkalies, it becomes yellowish.

Prussiate of Potass and Iron.

This compound is often called *prussian alkali*, or *prussian test*. The importance of it to chemists, consists in its being capable of indicating whether a metal be present in any solution whatever, unless the metal be platina; and the colour of the precipitate differing with the metal, even the name of the metal may be known. It is necessary to take great care to have it properly prepared, otherwise it will afford false results. We have given Henry's directions respecting its preparation at page 443. Its crystals should be preserved in a well-stopped bottle filled with alcohol, in which they are insoluble.

Of Crystallization.

Crystals are aggregations of the particles of bodies, which have been spontaneously disposed in a regular form; and crystallization denotes the act of their formation. According to the strict meaning of the word, a crystal should be transparent, as well as symmetrical in its form; but it is now extended to opake substances, and regularity of form is its leading characteristic.

Crystallization is of two kinds, the dry and the humid; dry crystallization refers to metals and other substances which cannot combine with water; the humid crystallization refers to fluids and gases holding solids in solution; and which never afford crystals but what contain more or less water.

The water combined with a crystal is called its *water of crystallization*. No crystals are transparent unless they contain water. The water, in thus combining with bodies, loses its caloric of fluidity.

The same substance, under the same circumstances, always affords crystals of the same figure; but excepting the circumstances which modify the natural process of crystallization, all

the differences observed in the forms of crystals, are attributable to differences in the forms of the integral particles of the crystals.

Crystallization cannot take place unless the particles of bodies be at liberty to arrange themselves according to their peculiar attractions. Hence it is necessary, either that they be in a state of solution, or suspended in a fluid in a state of extremely minute division, or in fusion. It has not been decisively proved that mere suspension will produce such a regular arrangement of particles as can be called crystallization; but admitting this to be possible, the division of the particles which form the crystals must be carried so far as scarcely to differ from solution, and the same explanation will apply as to solution.

Suppose we have a saturated solution of common salt in water; the particles of the salt are so completely dispersed through the water, and probably so far removed from each other, that the particles of the water exert a stronger attraction on them than they exert on each other: the solution therefore remains perfect; but let some of the water be evaporated; it is now evident that the same quantity of salt is contained in a less compass, the particles of the salt must have approximated each other, and are within the sphere of each others attraction, they therefore aggregate and form crystals, until the solution is of the same intensity as at first. If the evaporation be resumed, more crystals are formed in the same manner, until at last, by the evaporation of the whole of the water, the crystals are obtained dry.

The crystallization of a metal is not essentially different from an aqueous crystallization. The metal may be regarded as held in solution by caloric, and as the caloric of fluidity is withdrawn by the cooling of the metal, the case is correspondent to that of the reduction of the quantity of water in the aqueous solution, and the particles will arrange themselves according to their form. It must be obvious, that if the particles of the metal, or of the solid in solution, consist of cubes, they will aggregate in forms of one description, and if they are tetrahedrons, they must place themselves upon each other in another.

A fluid which has furnished all or the greater part of the crystals that can be obtained from it, is called *mother-water*.

In general, fluids at a boiling heat hold in solution a much larger portion of any matter than when cold, because caloric has a powerful effect in lessening the attraction of aggregation, and preventing particles which are very near from combining. Common salt, is, however, an instance of a salt which is nearly

as soluble in cold as in hot water; but it appears to be a general law, that salts of this kind require but a small quantity of the water of crystallization.

Salts which acquire moisture from the atmosphere, so as to become fluid or pulpy, are said to be *deliquescent;* when they lose their crystalline form in the air, and yet remain dry and powdery, it is because their water of crystallization has been abstracted, and they are said to be *efflorescent.* A salt is deliquescent, when it has a *greater* attraction for water than the air, as it will in that case take water from the air: a salt is efflorescent, when it has a *less* attraction for water than the air, for the air will then abstract water from it. When the salt has the same attraction for water with the air, it suffers no change.

The slower the crystallization, the larger, the harder, the more regular and transparent, the crystals which are formed. A rapid evaporation of a solution, therefore, produces imperfect crystals, the particles not having time to assume the exact arrangement to which they are naturally disposed.

Crystallization is promoted when the solution is furnished with some point at which it may commence. In a saturated solution, which exhibits no signs of crystallization, crystals will soon be observed if a thread be stretched through it. But if, instead of any foreign matter, a crystal of the substance in solution be introduced, the crystallization is still further promoted. Upon this fact Le Blanc founded a method of obtaining very large and perfect crystals. He selected the largest and most perfect crystals of a salt recently formed, and put them into a saturated solution of the same salt. As the side of a crystal in contact with the vessel receives no increase, they were turned daily. After a certain time, the largest and most regular crystals thus obtained were employed as the nuclei of still larger crystals by a repetition of the process.

Kirwan observed, that if two salts be held in solution by the same fluid, a crystal of either will cause that salt to crystallize which is of the same kind as itself.

Crystallization goes on but very slowly in closed vessels; and in most instances wholly stops: but Dr. Higgins inferred from his experiments that the atmosphere only facilitates the process in consequence of its pressure; and therefore a sufficient column of mercury, or any other pressure, has the same effect. Perhaps the experiment has not been tried in a proper manner: the pressure upon the surface of a fluid in a closed vessel containing air, is not less than when that vessel is uncovered.

The action of light has the effect of impeding and disturbing crystallization; and crystals are therefore larger and more regular when formed in the dark.

A very singular discovery was accidentally made by Hauy, respecting the elementary forms of crystals. Happening to take up an hexangular prism of calcareous spar, which had been detached from a group of the same kind, he observed that a part of the crystal was wanting, and yet that it presented a smooth surface. Attempting to detach a segment from the contiguous edge, he could not succeed, but the one next to it was easily divided. Proceeding thus to divide the crystal mechanically, in such a way that the separation was easy, and left smooth surfaces, and which did not happen unless in directions parallel to the first fracture, he found that the crystal changed its form as parts of it were separated, until at length it acquired a form that remained mathematically the same after any subsequent sections. On trying the experiment, he found, that other crystals of the same spar were reducible to the same unalterable form; and that crystals of other bodies were also reducible to fixed forms, of one kind or another. These fixed forms, therefore, he denominates the *primitive forms* of the crystals; and the other forms which crystals assume, he calls their *secondary forms.*

The primitive form of fluate of lime, Hauy found to be an octahedron; of sulphate of barytes, a prism with rhomboidal bases; of corundum, a rhomboid somewhat acute; of beryl, an hexahedral prism; of blende, a dodecahedron with rhomboidal sides.

Pursuing the path which these discoveries pointed out, with a rare combination of industry and ingenuity, he succeeded in delineating a system of crystallography, which, though yet in its infancy, bears the strongest indications of remaining consistent with the phenomena of nature, and therefore of obtaining a permanent reception in science.

Of Combustion.

Combustion is the union of a body with oxygen accompanied by the evolution of light and heat; and therefore every body which is capable of forming this union, is called a *combustible.*

Oxygen is retained in the gaseous state by the large quantity of caloric with which it is combined, and for which it has a strong attraction; but if any substance be presented to the

oxygen gas, that has a stronger attraction for oxygen than oxygen has for caloric, the consequence is, that the oxygen gas is decomposed, its particles unite with the substance thus presented to it, and a great part of the caloric being then left in an uncombined state, recovers the properties which are peculiar to it in that state, that is, it assumes the appearance of fire. The heat thus produced is the more intense, the greater the quantity of caloric which is liberated in a given compass and time; and these circumstances are dependent upon the strength of the affinity between oxygen and the substance which separates it from caloric, and the quantity of caloric required to saturate the product of combustion.

At the ordinary temperature of the atmosphere, bodies have either no affinity for oxygen, or usually a very weak one; hence they suffer no change, or the change which does take place is so slow, that though a combustion in effect, it is not called by that name, because neither light nor heat are perceptible to the senses.

When the temperature of a combustible is raised, its affinity for oxygen is increased; and when it is raised to a certain point, which varies according to the nature of the substance, the affinity becomes very strong, the combustion is consequently rapid and brilliant, taking, according to the phenomena it presents, the name of ignition, inflammation, decrepitation, detonation, and fulmination.

Light appears to form a component part of all combustible bodies, and to enter, as well as caloric, into the composition of oxygen itself. Hence, when oxygen by combustion enters into a new combination, part at least of the light held both by it and the combustible, is disengaged and flies off, as well as the caloric. In general it appears evident, that the light is furnished by the combustible, because the light furnished by different combustibles is of different colours, and the quantity of it is by no means proportionate to the quantity of oxygen consumed. For example, hydrogen in combustion combines with a greater quantity of oxygen than any other body; but the light afforded is inconsiderable.

Although the light furnished by combustion is not proportionate to the quantity of oxygen which enters into combination, and therefore is evidently not wholly furnished by the oxygen, yet the case is the reverse with the caloric evolved. The combustion of those bodies which combine with the greatest quantity of oxygen, always furnishes the greatest quantity of caloric, and therefore the combustion of hydrogen furnishes the most intense heat that can be produced, until

some other substance shall be found which combines with a greater quantity of oxygen.

Another proof that the chief part of the caloric extricated during combustion is furnished by the oxygen, which when it ceases to be a gas, has no longer occasion for it, is, that when the oxygen is in combination with a fluid, a combustible substance, for example, a metal, will abstract it from the fluid, but the usual phenomena of combustion do not appear, although the combination with oxygen is so rapid, that if the same quantity of oxygen had been derived from a gas, in the same time, these phenomena would have been exhibited with considerable splendour.

Bodies which have been once thoroughly burnt, which is only another way of expressing that they are saturated with oxygen, are incapable of undergoing combustion again, until some part or all of their oxygen is abstracted. To deprive them of oxygen is virtually to unburn them; and when no part of a combustible has been dissipated, but only changed by the new combination, the abstraction of the oxygen absorbed restores its pristine properties. This is the case with metals, which acquire by combustion a weight equal to the oxygen combined with them, and of course lose that acquired part of their weight when the oxygen which constitutes it is withdrawn; but vegetables and other combustible matters containing many volatile parts, when burnt in the open air, have these parts dissipated, and therefore the products they afford after combustion, weigh considerably less than the vegetables themselves, as they only consist of those parts which cannot be converted into gas.

We have stated that many substances, by their union with oxygen in combustion, are converted into acids; when this happens, the combustible is said to be *oxygenized;* when the product of combustion is not an acid, it is called an *oxide,* and the combustible is said to be *oxidized.*

The experiments which have proved the alkalies and earths to be metallic oxides, have tended materially to establish the conclusion, that all substances are either combustible, or combined with oxygen to the point of saturation; and if this be maintained, oxygen must, like caloric, have an affinity for every substance existing.

Of Water.

The composition of water has been already incidentally mentioned; it consists of 85 parts of oxygen, and 15 of hydrogen. It is a product of combustion, being formed whenever hydrogen is united to oxygen; for these two bodies are not known to be capable of uniting in any proportion but that which forms water. The proofs of the composition of water are complete; this fluid may be decomposed, that is, separated into the gases of which it is composed; or the gases may be converted into water.

Water is capable of existing in four different states, 1. that of ice; 2. that of water, or the liquid state; 3. that of steam, or the gaseous state; 4. in combination with crystals or other solids.

1. Ice is the simplest state of water; if entirely deprived of caloric, it would still be ice, only increasing in hardness as the caloric was abstracted. It is elastic, and when long kept much below the point at which it is formed, it becomes extremely hard. When pulverized, it is white. As one of the amusements of the court of Russia, in the severe winter of 1740, a palace was constructed entirely of ice hewn from the river Neva; and a cannon made of the same material, drove a hempen bullet through a board two inches thick at the distance of sixty paces. Water expands in passing to the state of ice, with a force that produces most astonishing effects; rending trees, and separating immense fragments, from rocks and mountains. This expansion is owing to the new arrangement of its particles; the needles of the crystals crossing each other, either at angles of 60° or 120°. Ice is converted into water when its temperature is raised above 32°.

2. Water retains its character as a fluid, at all temperatures between 32° and 212°. When the barometer is at 30 inches, and the thermometer at 60°, a cubic inch of water weighs 252.422 grains. It is employed as the standard of comparison in all tables of specific gravities, for reasons pointed out at page 80 of this volume.

Water, when perfectly pure, possesses a high degree of transparency, and is entirely destitute of colour, taste, and smell. It is nearly inelastic, and consequently incompressible. It can only be obtained pure by distillation; for as it is capable of holding a greater number of substances in solution than any other fluid, the facility with which it becomes impregnated with foreign substances must be obvious.

3. When water is converted into vapour, it combines with above five times the quantity of caloric which would be required to bring ice-cold water to the boiling heat; it is estimated to fill a space 1800 times greater than in the state of water; and the large quantity of caloric with which it is combined, is the only cause of the difference. This refers to water under the common pressure of the atmosphere. When this pressure is lessened, as under an exhausted receiver, water assumes the state of vapour at a very gentle heat; and when retained in a sufficiently strong vessel, as in a Papin's digester, it may be rendered red-hot, without being converted into steam. The elasticity of steam is prodigious; and it increases with the heat at which the steam is formed. It has been found by experiments, that the expansive force of steam exceeds that of gunpowder.

4. The singular tenacity with which water is held by a great number of substances, is an interesting fact. Saussure has proved that alumine will retain one-tenth of its weight of water, at a heat which will keep iron in fusion; lime retains water with nearly the same force; and calcined plaster of Paris is changed from the state of a powder to that of a solid, by combining with a large portion of water; some salts, though tolerably hard and dry, are combined with as much water as at a boiling heat would hold them in solution; crystals owe their transparency, and even their solidity, to the water combined with them, for they lose both these properties as soon as the water is abstracted. By entering into many of these combinations, it is evident that water is deprived of a greater quantity of caloric than in the state of ice, and it is to this cause that we must attribute its hardness in gems.

Mineral Waters.

The purest water which nature affords, is that of melted snow, or of rain newly fallen, and collected in the open fields, at a distance from houses, or contaminated atmosphere. The water of rivers and lakes is the next in purity, especially where it has a rocky or gravelly bed. Stagnant water, and that of marshes, is in general exceedingly impure, and often offensive to the taste, as it is largely impregnated with principles derived from the putrefaction of animal and vegetable matters. All these waters, however, possess the property called *softness*, that is, they will dissolve soap. Spring-waters are generally hard; they will not dissolve soap, and are therefore unfit for many domestic purposes, and for manufactures. This arises from their containing earths and minerals in solution. Springs which supply water of a more agreeable taste than rain, river,

or lake water, are the most abundant, and they always contain carbonic acid. Other impregnations impair their taste, and when they are in such excess as to give a marked character to the water, the waters of such springs are called *Mineral waters*.

It may often be important to obtain a general idea of the impregnations of a particular spring, in order to know whether it can be safely taken with food, or is likely to be useful as a medicine, or ought to be wholly rejected. We shall therefore give a short account of the tests by which the most usual impregnations may be detected.

The sensible qualities of the water, such as transparency, colour, taste, and smell, should be examined, if possible, at the instant it comes from the spring. If the water must necessarily be examined at a distance, a bottle with an air-tight stopper, should, at the fountain-head, be completely filled with it, in order to leave no space for air. The specific gravity of the water should also be taken. To note exactly the sensible qualities of the water, will often indicate the re-agents which may be employed to discover its composition.

Spring-water generally contains more or less carbonic acid, which imparts an agreeable sparkling and briskness, like that exhibited by fermented liquors; when no colouring matter is present, the sparkling induces us to suppose this water more transparent than other water. Carbonic acid sinks the taste of every other ingredient in waters; and therefore such waters should not only be tasted at the spring, but some time after they have been exposed to the air, or after they have been boiled, as the carbonic acid will then have escaped. The tincture of litmus will discover whether an acid is present in water, and as the carbonic is the only acid which is separated by exposure to the air, this exposure, if it deprive the water of the power of reddening litmus paper or its solution, will shew whether the acid is the carbonic or not.

Water containing carbonic acid will hold a considerable quantity of carbonate of lime in solution. Lime is detected most effectually by the oxalic acid, which separates it from all its combinations, and forms with it an insoluble precipitate, unless an excess of acid be present, for then the precipitate will be re-dissolved. It is therefore best to use the oxalate of ammonia or potass, in order that the alkali may neutralize the acid in solution.

Diluted muriate of barytes will form a precipitate with water containing sulphuric acid. The precipitate is white, and insoluble in diluted muriatic acid.

The nitrate of silver occasions a white precipitate or cloud in water containing muriatic acid.

Alkalies held in solution, or alkaline or earthy carbonates, change paper stained with turmeric to a brown, or reddish brown, and light vegetable reds are rendered blue. The volatile alkali may be distinguished by its smell. Earthy and metallic carbonates are precipitated by boiling.

Iron is very common in mineral waters; it may be detected by its forming a purple or blackish precipitate with tincture of galls, or blue with prussiate of potass.

Pure ammonia, or lime-water, precipitates magnesia and alumine, and no other earths, provided the carbonic acid has been previously separated by a fixed alkali and boiling.

The mineral acids, when uncombined, give a permanent red to litmus paper, both before and after the water has been boiled; whereas the redness communicated by the carbonic acid goes off as the paper dries.

The waters called sulphurous, contain sulphuretted hydrogen, which may be detected by its peculiar smell, also by the vapour tarnishing silver, and blackening paper which has been dipped into a solution of acetate of lead.

Waters containing the sulphate of copper, may be detected by their giving the colour of copper to a polished plate of iron immersed in them.

Sulphate of iron is precipitated by alcohol.

The specific gravity of sea-water is generally 1.0289. It holds about $\frac{1}{30}$th of its weight of muriate of soda in solution, with a small quantity of muriate of magnesia, and a still smaller proportion of sulphate of lime. At a distance from land, it is colourless and void of smell, but intensely saline and bitter.

In analyzing waters with exactness, the gaseous products they afford are carefully collected and examined.

Of the Air.

The atmosphere may be said in general terms to consist of oxygen and nitrogen; but atmospheric air, even when purest, always contains a small proportion of other principles. Murray states its exact composition as follows.

	By measure	By weight
Nitrogen gas	77.5	75.55
Oxygen gas	21.0	23.32
Aqueous vapour	1.42	1.03
Carbonic acid gas	.08	.10
	100.0	100.0

As considerable quantities of hydrogen escape from the earth, it might be presumed that it would be found in atmospheric air; but as atmospheric air has no chemical attraction for it in any proportion that can be detected, it probably escapes, by its levity, beyond the heights to which we have access. Dalton's experiments evince that the proportion of carbonic acid gas does not exceed a thousandth part, though a higher estimate is generally made.

Atmospheric air is destitute of taste and smell, highly compressible, and perfectly elastic. It supports animal life, directly by the oxygen it affords to the lungs, where the blood combines chemically with it; and indirectly, by its mechanical properties in equalizing the temperature of the globe, and preventing too rapid an evaporation of the moisture of the body. It is also not less necessary to vegetable life, as the vehicle for the distribution of water, and in its decomposition, by furnishing them with nitrogen, carbonic acid, and other principles.

Atmospheric air contains the only proportion of oxygen which is subservient to the purposes of existence: all the known gases have been tried; none of them except the nitric oxide can be breathed for even a few minutes; and even the nitric oxide, during the short time in which it remains on the lungs, produces a suspension of the proper functions of the mind. In all the other gases, also, combustion is either intemperate or wholly stopped. Notwithstanding the multiplied compositions and decompositions which are continually going on at the surface of the earth, the due proportion of oxygen in the air is still maintained with a precision truly astonishing.

The specific gravity of air is less, the greater the proportion of aqueous moisture which it contains. Hence aëronauts find that their balloon sinks when passing over the sea, where the air is moister than over the land.

ORGANIC SUBSTANCES.

VEGETABLES.

Vegetables, though infinitely diversified in their appearance and properties, are found to consist of a small number of simple substances; carbon is the basis of them all, and after carbon, hydrogen and oxygen may be considered as forming the principal part of them. Some vegetables contain nitrogen, others phosphorus, earths, and metals, but these elements are not general; they belong only to particular plants, or to plants in particular situations.

Although the proportions of the component parts of vegetables may be ascertained with considerable accuracy, yet the chemist is unable to combine these component parts in any manner that shall produce substances resembling the entire vegetable, or the compounded products which it affords.

Plants derive a principal part of their nourishment from water; their roots imbibe the water, which is decomposed in them, by the assistance of light and heat; and a part of its hydrogen becomes fixed, while part, at least, of the oxygen is given out by transpiration. Water will hold carbon in solution, deriving it from the soil; and hence the utility of dung, or putrefying animal and vegetable substances, which supply a large quantity of carbon, as well as hydrogen and nitrogen. Plants will grow, although their roots stand in such materials as lose no portion of their weight, and although they be watered with distilled water. In this case, the carbon of the plant is derived from the atmosphere, through the medium of the leaves. Perhaps at all times the atmosphere furnishes a part of the carbon, through the medium of the under surface of the leaves; but when an adequate supply is derived from the roots, the leaves perform this office with less energy. Water impregnated with carbonic acid gas, renders vegetation more vigorous.

The processes of vegetation have a considerable tendency to produce equality of temperature. If the bulb of a thermometer be plunged into a hole in a tree, it indicates a higher temperature than the atmosphere in cold weather, and a lower temperature in hot weather.

The most usual compound substances furnished by vegetables, and which are possessed of remarkable or distinct characters, we shall now proceed to consider separately.

Sugar.

Sugar is afforded by most plants, and in some, such as the sugar-cane, the beet-root, the sugar-maple, the carrot, it is particularly abundant. It crystallizes, is sweet to the taste, and soluble in water and alcohol. Used as food, it is extremely nourishing and antiseptic. Treated with nitric acid, it affords oxalic acid. Lime, barytes, magnesia, and strontian, are soluble in the solution of sugar. One hundred parts of sugar, contain of carbon 28 parts, of hydrogen 8, and of oxygen 64.

Mucilage, or Gum.

Mucilage is soluble in both hot and cold water; the solution is adhesive; it exists in many bulbous roots, particularly the bulbs of the hyacinthus non scriptus, or common blue-bell; and it exudes from the trunks of certain trees, such as the cherry-tree. When hardened in the sun, or reduced to the solid state by the loss of moisture, it is brittle and almost transparent; it then takes the name of *gum*. Gum arabic is a very pure mucilage.

Mucilage consists of the same component parts as sugar, with a small proportion of nitrogen and lime.

Starch, or Fecula.

Starch is white, insipid, insoluble in cold water or alcohol, but forming with boiling water a semi-transparent jelly. It is abundant in potatoes, wheat, barley, and many other plants, roots, and seeds, and may be separated from them by maceration in water. It dissolves in cold water that contains an acid or an alkali.

Fecula is often used as a general term for all matters contained in the juices of plants, and not held in solution by them; sometimes we hear of *amylaceous fecula;* this is the same with starch; *green fecula* is also an expression in use, but the green colour of fecula is seldom permanent. Indigo is a blue fecula.

Gluten.

If wheaten flour be kneaded in cold running water, the water will carry off the mucilage and starch it contains; but when the water runs off colourless, a peculiar substance will remain, which is called *gluten.*

Gluten composes about one-twelfth of the matter of wheaten flour, it is ductile and elastic, and of a stringy texture; it has some smell, but no taste. If stretched out, it returns to its original state. By exposure to the air, it becomes brown, and appears to have an oily coating. When completely dry, it is very brittle, and resembles glue. If kept moist, it soon putrefies. It is insoluble in water, alcohol, or ether; but the acids dissolve it, and the alkalies precipitate it. No other vegetable product has so near an alliance to animal matter both in its appearance, which is like that of tendons, and in its constituent parts, into which nitrogen largely enters, and some ammonia.

Albumen.

Albumen is most abundant in those vegetables which ferment and afford a vinous liquor without yeast. It is soluble in cold water; but its chief characteristic is, that it coagulates and becomes insoluble by heat.

Gelatine.

Gelatine, or jelly, has some resemblance to albumen, but differs from it in not being coagulated by heat. It is soluble in water, insipid, and precipitated by infusion of galls. It may be procured from blackberries and other fruits of a similar kind.

Bitter Principle.

The bitter principle of vegetables is soluble in water and alcohol. It is soluble in nitric acid, and precipitated by nitrate of silver; its colour is yellow or brown. Hops, quassia, &c. contain much of it.

Narcotic Principle.

The narcotic principle is soluble in 400 parts of hot water; alcohol dissolves a twenty-fourth part of it; it is crystallizable, and of a white colour. It is soluble in all the acids without heat, and is precipitated from them in a white powder by alkalies.

Extractive Matter.

Extractive matter is taken up from vegetables by water and alcohol, and therefore is soluble in these fluids. It is insoluble in ether. It is precipitated by oxymuriatic acid, muriate of tin, and muriate of alumine, but not by gelatine. It dyes a fawn colour. In the roots of liquorice it is abundant.

Tannin.

Tannin is the name given to the peculiar principle which combines with the gelatine of skins, and converts them into leather. It is found in the gall-nut, and in all vegetables or parts of vegetables which are called astringent. It has by some been deemed the astringent principle. It is soluble in water and alcohol, but is precipitated by gelatine, with which it forms an insoluble compound that becomes solid and elastic.

Fixed Oils.

The fixed oils, afforded by vegetables, are in nearly all cases extracted from the seeds: when pure, they have no smell, and very little taste; they are insoluble in water and alcohol, and very combustible: they form soaps with alkalies. Their boiling point is higher than that of water, and when, by increasing the heat, they are volatilized, they are decomposed at the same time. Most of them freeze a few degrees above the freezing point of water. Their specific gravity is generally less than that of water. Some fixed oils, the principal of which are poppy-oil, nut-oil, and linseed-oil, have the property of drying when exposed to the air; when dried alone, their transparency remains. The property of drying is attributed to the absorption of oxygen. These oils are used in painting, but not for making soap.

Fixed oils are generally obtained by pressure from the seeds which furnish them. Lavoisier determined olive-oil to consist of carbon 78.92, and hydrogen 21.08.

Volatile Oils.

Volatile or essential oils have a strong taste, which, though hot, is often not disagreeable; they have also a penetrating, aromatic smell, and are volatilized at the heat of boiling water; most of them are soluble in alcohol and acetic acid, but not in water. They are generally obtained by distillation with water, but sometimes by expression, as from the rinds of lemons and oranges. They are obtained from all the parts of plants except the seed. They are highly inflammable, and

when burnt they leave no residuum. In consistence they are found in all states, from extreme fluidity to solidity. When employed as internal medicines, they are too pungent and acrid to be taken alone, but if dropped upon dry loaf sugar, such of them as are suitable, may be taken without difficulty.

Camphor.

Camphor is a concrete volatile oil. It has a strong but agreeable smell, and an acrid taste. It swims on water, burns without residuum, and is so volatile as entirely to exhale when exposed to a moderate temperature. It is, when pure, in crystals, which are white, brittle, but not so hard as to prevent their being easily crumbled. Camphor is soluble in alcohol, ether, and fixed oils.

Wax.

Wax is in its composition very analogous to fixed oil. It is a vegetable product: bees are merely the labourers by whom it is collected; they do not alter its nature. If the nitric or muriatic acid be digested for several months upon a fixed oil, the oil passes to a substance resembling wax. Hence wax might be inferred to be a fixed oil concreted by the absorption of oxygen. Its natural colour is yellow, but it may be whitened by exposing it in thin lamina to the air and sun. Alkalies dissolve wax, and render it miscible with water.

In China and in North America, wax is obtained directly from plants, and is then called vegetable-wax.

Honey.

Honey, like wax, is gathered by bees, ready formed, from flowers, which contain it in an organ called the nectary; it is deleterious when gathered in districts where poisonous shrubs abound, of which there are many examples in the uncultivated parts of America. Honey is composed of sugar, mucilage, and water.

Resins.

Resins are mostly insoluble in water, but when pure they are soluble in alcohol, oils, ether, alkalies, and acetic acid. They are sometimes brittle. sometimes soft and tough, and they all become fluid by heat. The nitric acid converts them into tannin. By distillation, they afford volatile oil. They are all electric, and their electricity is negative. During combustion, they afford much smoke.

If a volatile oil be exposed to the air, after the lapse of a considerable time, it thickens, and is gradually converted into resin ; it has lost some carbon, and acquired oxygen, to which the change must be ascribed. Resins either exude naturally, or are obtained by perforating the trunks of trees.

Balsams.

Balsams have a strong and fragrant smell, most of them are semi-fluids. When heated, the benzoic acid sublimes from them, which constitutes the principal distinction between them and resins. Like resins, they are obtained by incisions made in the trees affording them.

Gum Resins.

Gum resins are distinguished from common resins by their forming milky solutions with alcohol, and by their being infusible. Their solutions with alcohol are transparent. Frankincense, scammony, aloes, and gum ammoniac, are gum resins.

Both gum resins and balsams afford tannin when treated with nitric acid.

Caoutchouc.

Caoutchouc, elastic gum, or Indian rubber, possesses great elasticity; is insoluble in water and alcohol, is reduced to a pulp by heated spirits of turpentine, but is strictly soluble only in nitric ether and naphtha. The solution is extremely adhesive, and slow in drying.

Caoutchouc always remains soft, like leather, unless in a very low temperature; it is fusible, and burns like resins, but with less smoke.

Bird Lime.

Bird-lime is of a greenish colour, has the smell of linseed-oil, is insipid to the taste, and is extremely viscid. It is perfectly soluble in ether, sparingly so in alcohol, and insoluble in water. By exposure to the air, it becomes dry enough to be powdered, but recovers its viscidity by wetting it. It red dens tincture of litmus.

The best bird-lime is supplied by the middle bark of the holly, which is boiled in water, left to ferment for several weeks, and afterwards macerated in water.

Colouring Matter.

The colouring matter of vegetables is combined with, 1, the extractive principle; 2, with resin ; 3, with fecula; 4, with gum.

Most of the colouring matters of vegetables have a great affinity for the earths, particularly for alumine; and for the white metallic oxides, especially the white oxide of tin; also for animal fibrous matters, and for oxygen. On a due regard to these affinities, depends the art of dyeing.

Berthollet remarks, that those colouring matters which contain the most carbon, afford the richest and most lasting colours. Indigo is of this class.

Woody Fibre.

When thin shavings of wood are boiled in water, to separate the extractive matter, and afterwards in alcohol, to dissolve the resin, a residuum is obtained called the *woody fibre.* It constitutes the basis of the solid part of vegetables. It is tasteless, insoluble in water or alcohol; but is soluble in weak alkaline solutions, and is precipitated by acids. It is also soluble in nitric acid, and yields oxalic acid. It is not liable to putrefaction by exposure to the air. It consists principally of carbon, and therefore, when burnt in close vessels, affords much charcoal.

Animal Substances.

Animal substances present us with the same constituent principles as vegetables; but the proportions of these principles are different. By destructive distillation they afford much ammonia, which is sparingly distributed in the vegetable kingdom; they also contain much nitrogen, of which the proportion is usually small among vegetables; and they are more abundant in phosphorus; while of carbon and hydrogen, which are abundant in vegetables, they contain but little. They are also distinguished from vegetables by their undergoing only the putrid fermentation, while vegetables, previous to this fermentation, undergo one of which the product affords alcohol, and another which affords vinegar.

The distinct compound substances derived from animals, are very numerous; we can only notice the most important and general.

Gelatine.

Gelatine, or jelly, is supplied by all the parts of animals, even bones, but is most abundant in the soft and white parts. It is perfectly soluble in warm water, but insoluble in alcohol, and has little taste or smell; on cooling, when not diffused in too large a quantity of water, it has a soft tremulous consistence, and becomes fluid by an increase of heat. Gelatine is

prepared for the table from calves' feet and the muscular parts of animals. It is a substance strongly tending to putrefaction when combined with water, and it differs from vegetable jelly chiefly in this tendency; but if it be concentrated and dried in a stove, it may be kept in a dry place for many years. In this state it forms the preparation called portable soup; it is still easily soluble in boiling water, and a very small quantity of it forms a basin of soup.

When gelatine is obtained from the skin, cartilages, and refuse of animal matter, and reduced only to the consistence of a jelly, it is used in the arts under the name of *size*. When the gelatine is concentrated and dried, it forms *glue*. The strongest glue is afforded by old animals. Isinglass is a glue which consists of the air-bladder of the beluga; a species of fish plentiful in the rivers of Russia.

Gelatine is dissolved both by acids and alkalies. Tannin forms with it an insoluble compound.

Albumen.

Albumen, or coagulable lymph, exists in its purest natural state in the whites of eggs, which consist almost entirely of it; it is also abundant in the humours of the eye, and the fluid of dropsy. Its properties are similar to the albumen of vegetables. It is soluble in water, before it has been coagulated by heat, but not afterwards. Alkalies dissolve the coagulum.

Albumen is coagulated by acids, and in some degree by alcohol. It speedily putrefies.

Oils.

Animal oils are generally solid at the ordinary temperature of the atmosphere, especially when obtained from land animals. They are distinguished by the names, tallow, lard, suet, butter, fat, marrow, &c. Fish afford fluid oils, the most common of which is train-oil, obtained from the whale; spermaceti is an exception, it is a fixed oil obtained in a concrete state from the brain of a particular species of whale.

Animal oils contain more oxygen than vegetable oils, and those which concrete the soonest contain the most of this principle. They yield sebacic acid, and they unite with alkalies to form soap.

Fibrin.

If the muscle of an animal be macerated in cold water, afterwards digested in alcohol, and in boiling water, to remove all the parts soluble by these agents, a white, insipid, fibrous substance remains, which is called *fibrin*.

Fibrin forms the principal part of the muscle. It is insoluble in water, alcohol, ether, or oils; it has neither taste nor smell; it contracts when heated, and by a stronger heat is melted. It is soluble in acids and alkalies, but not in cold liquid ammonia. Alkalies precipitate it from acids in flakes, which are soluble in hot water, and resemble gelatine. With nitric acid, it affords more nitrogen than any other substance. By destructive distillation, it affords water, carbonate of ammonia, a thick, heavy, fetid oil, traces of acetic acid, carbonic acid, and carburetted hydrogen. It also contains some phosphate of soda and of lime.

Fibrin exists in blood, by which it is deposited on the muscles. If the clotted or coagulated part of blood, be tied up in a linen-cloth, and washed in water till the water ceases to receive either colour or taste from it, fibrin will remain in the linen.

Fibrin has a very near resemblance to gluten.

Bones.

Bones derive solidity from the phosphate of lime, which forms a considerable part of them; cartilages, which are bones in the first part of their formation, have the properties only of coagulated albumen. The gelatine and fat combined with bones, impart toughness and strength, and hence, when their quantity is diminished by age, the bones are easily broken. One hundred parts of ox-bones, according to the analysis of Fourcroy and Vanquelin, are composed of solid gelatine 51, phosphate of lime 37.7, carbonate of lime 10, phosphate of magnesia 1.3.

The enamel of human teeth contains a greater quantity of the phosphate of lime, and is destitute of gelatine. The shells of animals are a species of bones; they contain about the same quantity of carbonate of lime, that the bones of perfect animals contain of phosphate of lime.

Horn.

Horns, hoofs, nails, and quills, differ but little in their chemical characters; they are found to consist chiefly of condensed albumen, with some oil, and a very small proportion of gelatine and phosphate of lime.

Stag's horn and ivory are nearly the same as bone, and contain much gelatine.

Hair, wool, and feathers, differ but little from each other in their composition; one fourth of their weight consists of oil, on which their colour depends; they afford besides, water, ammonia, carbon, silex, and iron. Hair is soluble in alkalies, with which it forms soap.

Blood.

Blood, recently drawn from an animal, appears to be a thin and homogeneous fluid; but it soon separates into two parts, the one a coagulated part, called the *crassamentum;* the other a fluid, called the *serum.*

The crassamentum is of a red colour; it contains albumen, iron, soda, and fibrin; the fibrin constitutes it basis, and may be obtained separately by washing it in water. It has all the properties of the fibrin obtained from muscular fibre. The crassamentum has a specific gravity of 1.245, whereas that of blood is only about 1.05.

Serum is of a light greenish yellow colour. Its taste is slightly saline, and it turns sirup of violets green; this property it owes to the uncombined soda which it contains. It is coagulable by a temperature of 156°, and is then of a grayish white colour; it therefore contains a large proportion of albumen; it also contains gelatine, hydrosulphuret of ammonia, soda, muriate of soda, phosphate of soda, and phosphate of lime. Acids permanently coagulate serum; alkalies increase its fluidity; alcohol coagulates it, but the coagulum is soluble in water.

When the blood, after circulating through the body, has arrived at the lungs in its way to the heart, it has acquired a dark colour; but when, in the lungs, it has been exposed to atmospheric air, it absorbs oxygen, with a minute portion of nitrogen, and parts with carbon; the consequence of this operation is its acquiring an increase of heat, and a fine crimson colour.

Milk.

Milk is usually considered as consisting of three parts, the *caseous, butyraceous,* and *serous,* which, upon its being allowed to stand in an open vessel, spontaneously separate from each other.

The butyraceous part or cream rises to the surface, and when designed to furnish butter, it is skimmed off, and being put into a vessel, in which it can be rapidly agitated, the butter separates from it. Butter, when fluid, is transparent, but it becomes opake as it cools and hardens. The butter of cow's milk becomes harder than that of any other animal.

The caseous or cheesy part of milk is obtained by coagulating milk with an acid; for this purpose, in preparing cheese from cows' milk, rennet is used, which is the stomach of a calf in which milk has soured. The coagulum is separated from the fluid part to make cheese.

After the whole of the matter which is capable of coagulating is separated from milk, the serous or watery part only remains; but rennet, from its slight acidity, does not make a complete separation. The fluid therefore remaining, after rennet has been used, still contains saccharine particles and curd, and under the name of *whey*, is used as a wholesome beverage. The serum obtained by the spontaneous decomposition of milk, is acidulous, and totally devoid of nourishment.

If sweet whey be evaporated to the consistence of honey, and afterwards dried in the sun, a solid substance is obtained, which is called *sugar of milk*. If the sugar of milk thus prepared be dissolved in water, it may be clarified by whites of eggs, and will afford white crystals after being evaporated to the consistence of a sirup. Sugar of milk is soluble in three or four parts of water; its taste is slightly sweet, and it yields by distillation nearly the same products as other sugar.

Milk is capable of undergoing the vinous fermentation, and consequently of affording a spirituous liquor. Marco Polo, who wrote in the thirteenth century, asserted that liquor prepared from mare's milk by the Tartars, might be taken for white wine. If milk be deprived of its cream, it will not afford a spirituous fluid.

Thenard gives the following as the component parts of milk: 1, water; 2, acetous acid; 3, caseous, 4, butyraceous, 5, saccharine, and 6, extractive matter; 7, 8, muriate of soda and potass; 9, sulphate of potass; 10, 11, phosphates of lime and magnesia. The acid here called the acetous, is now found to have different properties, and is called the *lactic acid*, see p. 442. The milk of different animals differs in its composition; ass's, mare's, and woman's milk, are the most saline and serous; cow's, goat's, and sheep's, contain the most of the caseous and butyraceous parts.

Of Fermentation.

When vegetables and animals are deprived of life, the elements of which they are composed exert an action on each other; some of them enter into new combinations, others become entirely undecompounded; and the identity of the original substance is destroyed.

Fermentation is of three kinds: 1, the vinous; 2, the acetous; 3, the putrid. The two first kinds are peculiar to vegetable substances; the last is common both to vegetable and animal substances, though the change it indicates, is, in reference to animal substances, more generally called putrefaction. Mois-

ture, and generally access of air, are necessary to fermentation, and a warm temperature materially promotes it, while by an excess either of heat or cold it is entirely checked.

Vinous Fermentation.

The vinous fermentation never takes place except in substances containing sugar, and it is most remarkable in those which contain the most of the saccharine principle.

If a decoction of a vegetable holding much sugar in solution, or saccharine vegetable juices, or simply a mixture of sugar and water, be exposed to a heat of 70°, in a vessel either uncovered or not entirely closed, in a short time the fluid becomes turbid, bubbles rise to the surface and break; mucilage is at the same time disengaged, part of which sinks to the bottom, and the remainder rises to the top, where, with the bubbles entangled in it, a stratum is formed called *yeast*. When the quantity of the fermented fluid is considerable, the operation goes on briskly for several days, afterwards it becomes gradually more languid, but it is a considerable time before it comletely ceases.

A fluid which has undergone the vinous fermentation, is entirely changed in its properties; its specific gravity is diminished; its sweet taste and viscidity is gone; it becomes brisk and transparent, and has acquired a pungent spirituous flavour. It forms beer, cider, wine, &c. according to the substance which has furnished the saccharine juice; and from whatever it has been prepared, it affords, by distillation, a light inflammable fluid called *alcohol*.

From the experiments of Lavoisier, it appears that sugar is converted into alcohol by the loss of a part of its oxygen. The oxygen separated is employed to form carbonic acid gas, which produces the bubbles observed on the fermenting liquor.

A small quantity of yeast is always added to liquors intended to be fermented, as it materially accelerates and renders uniform this process through the whole mass of fluid.

Acetous Fermentation.

When liquors are fermented for the use of the table, they are put into casks while the fermentation is yet active; at first the bung-hole is left open, and as yeast is discharged, the barrel is filled up with a part of the fluid or wort reserved for that purpose; afterwards the vessel is closed. But if the fluid be allowed to remain a sufficient time in open vessels, the acetous fermentation comes on, which changes its taste and smell, and

converts the fluid into *vinegar*. This change takes place most rapidly at the temperature of about 90°, and is promoted by changing the surfaces of the liquor, by stirring it or pouring it from one vessel to another.

During the acetous fermentation, the alcohol imbibes oxygen, to a degree that converts into an acid; and if the liquor which has undergone this process be distilled, pure vinegar, instead of ardent spirit, comes over.

Simple mucilage will pass to the acetous fermentation, without being preceded by the vinous, or at least the vinous fermentation is so transient as not to be discernible.

Wines deprived of mucilage cannot be converted into vinegar.

Putrid Fermentation.

When dead vegetables contain much saccharine matter, and the other circumstances necessary to fermentation are combined, the vinous, the acetous, and the putrid fermentation succeed each other in regular order; when mucilage is the predominant principle of the vegetable, the acetous fermentation, above described, is the first change discoverable, the putrid follows of course, as it is always the last; but the vinous does not appear: when albumen and gluten are predominant in the vegetable matter, the putrid fermentation only is apparent.

We have observed the progress of a saccharine fluid from the vinous to the acetous fermentation, let us now trace it to the putrid: when vinegar has been completely formed, and the warmth and exposure to the air in which it was formed are still continued, it gradually becomes viscid and turbid; an offensive gas is emitted, ammonia flies off, an earthy sediment is deposited, and the remaining fluid scarcely differs from water. Such is the change produced by putrefactive fermentation in a saccharine fluid.

When moist vegetables are heaped together in considerable quantities, their putrefaction is attended with the production of considerable heat, their whole texture becomes less coherent, their colour dark, and nitrogen, hydrogen, carbonic acid, and ammoniacal gases, begin to be evolved. When the putrefactive process has advanced to this stage, the vegetable matter affords excellent manure; for it is obvious, that the principles of vegetables are liberated, and are ready to nourish the seed or the root to which the manure is applied, while the warmth with which the decomposition is attended, enables the seed or root more readily to receive the food thus offered.

The putrefaction of animal substances goes on under the same

circumstances that promote the putrefaction of vegetables,—humidity, a temperature neither hot nor cold, and the access of the atmosphere, but it is distinguished by a far greater noisomeness. The presence of the air is the least essential particular; for putrefaction goes on in vacuo, the air required being supplied by the decomposition of water. A very small quantity of salt hastens putrefaction, while a considerable quantity remarkably retards it, and is therefore used in the preservation of animal food. The first indication of putrefaction in animal substances, is a cadaverous odour, their substance becomes soft, pale, then green, blue, and lastly a blackish brown; the smell at the same time becomes more nauseous and penetrating, ammoniacal gas is perceived, other gases also escape, which are of an infectious and poisonous nature; in the end, the substance loses all traces of organization, becomes dry, soft, and reduced to a state resembling that of an earth.

The worms and insects generally found among putrefying substances, are not produced by putrefaction, and therefore not a necessary consequence of it; life never springs but from life; and the maggots are there, because the insects from which they spring, directed by instinct, have deposited their eggs among matter suitable for their food.

Of Alcohol.

Alcohol, or the purely spirituous part of liquors which have undergone the vinous fermentation, and no other, is transparent and colourless like water; its taste is highly pungent, but agreeable. It is extremely inflammable, and when set on fire it leaves no residuum. Its specific gravity is 0.800; and from its lightness and extreme fluidity, the bubbles which are formed on its surface, break with rapidity. It is not frozen even by the extreme cold of —65°, but it has been frozen by the sudden abstraction of its caloric in the vacuum of an air-pump. In a vacuum, it boils at 56°; in the air it is converted into vapour at 55°, and boils at 165°. It is from its being converted into vapour much sooner than water, that it is easily separated by distillation from wine, beer, and other liquors which contain it. All these liquors owe their strength to the quantity of alcohol they contain: the best port-wine contains about one-fourth of its bulk of alcohol. Brandy, rum, and whisky, contain still more alcohol. Proof spirit is half water and half alcohol.

The alcohol obtained by distillation always contains some water; from which that operation will not free it; to obtain

pure alcohol, therefore, perfectly dry potass, obtained by exposing this alkali for some time to a red heat, is put into it: the water having a stronger affinity for the potass than for the alcohol, combines with the alkali, which falls to the bottom, and the alcohol may be drawn off with the siphon. Afterwards the alcohol should be distilled with a gentle heat, and not quite to dryness, that any potass it may contain may be left behind.

Alcohol mixes with water in all proportions, and the combination is so intimate that the mixture takes up less space than the fluids separately; and therefore, as in every other combination where such an effect happens, caloric is extricated, and may be felt by the hand.

Alcohol is the grand solvent for resins, and is much used for making varnishes. Camphor dissolves in it very readily, and the solution hastens that of some substances upon which the alcohol alone acts but slowly, or not at all, particularly copal.

Alcohol takes up a small portion of phosphorus, which is precipitated by water. Quicklime alters the flavour of alcohol, and renders its colour yellow; though the earths in general, and metallic oxides, appear to have no action upon it. Both fixed and essential oils are soluble in alcohol.

The composition of alcohol is not accurately known. The analysis of Lavoisier indicated that 100 parts of it contain of carbon 30, of hydrogen 7.5, and of water 62.5; but the accuracy of the analysis is doubtful, for as it was conducted by burning the alcohol in oxygen, part of the water may have been the produce of combustion, as Fourcroy and Vanquelin have clearly proved that alcohol contains oxygen. However this be, the manner in which the component parts of alcohol are united, remains entirely a mystery.

Betancourt has ascertained the important fact, that the vapour of alcohol has more than double the expansive force of that of water of the same temperature; and that the steam of alcohol at 174° is equal to that of water at 212°. Hence it has been suggested that alcohol may be employed with advantage as the moving power of steam-engines, with a great saving of fuel, and consequently of expense, when means shall be contrived to save the fluid from being lost.

Of Ether.

If alcohol be mixed with its own weight of sulphuric acid, gradually added to prevent explosion, and the mixture be distilled in a sand-bath, the first product obtained is alcohol, but afterwards a very different fluid, which is equal in quantity to half the alcohol employed. This fluid is called *ether*.

Ether is still more inflammable and volatile than alcohol, and equally as colourless. It is the lightest of all known fluids; its smell is fragrant and agreeable, but not powerful. Its taste is hot and pungent. Its combustion yields a blue flame, and rather more smoke than alcohol. It boils at 98°. It may be obtained of the specific gravity of .716. It is a valuable medicine; being used externally for the headach or toothach, by pouring a little upon the hand, and pressing it upon the forehead, or cheek, till the pain it occasions goes off. Its internal use extends to all spasmodic affections.

The nature of the change produced on alcohol by the acid, when ether is formed, is not well understood; but it is supposed that ether contains a much larger proportion of hydrogen in proportion to its carbon.

If the distillation of ether be continued till sulphurous vapours appear, and the recipient be then changed, a new product is obtained; it is called the *sweet oil of wine*, which is unctuous, thick, less volatile than ether, and of a yellow colour. The last product obtained by urging the fire, is sulphuric acid and acetous acid.

Instead of the sulphuric acid, ether may be prepared with the nitric, the oxymuriatic, the acetic, and several other acids. According to the acid employed, its properties differ a little: nitric ether is often made, but the sulphuric is the most common and the most valued. The peculiar properties of the ethers made with different acids, have not been minutely examined.

Sulphuric ether acts upon most resinous substances; it is the best solvent of caoutchouc; it dissolves also the essential oils and camphor; mixes in all proportions with alcohol, but water only dissolves a tenth of it. It combines with caustic volatile alkali; but not with the fixed alkalies or lime. It dissolves a little sulphur and phosphorus.

If the ether obtained emit a sulphurous odour, it must be purified by a second distillation, previous to which it should be mixed with a little potass, which will combine with the acid, and in part with the water.

TABLES OF SIMPLE ELECTIVE ATTRACTION.

The chemical history of a substance, is constituted by a history of its affinities, or in other words, by an account of the effects which it produces when combined, either in the humid or the dry way, with other bodies. Geoffry, who wrote about the year 1718, was the first person who thought of representing the different affinities of bodies in a tabular form; and the idea so happily suggested by him, has been followed up by Bergman, and all subsequent chemists of eminence, with great assiduity. His method consisted in placing any given substance at the head of a column, and then placing the names of other substances which unite with it underneath, in the exact order of their affinity for it, placing those first, whose affinity is the strongest. Tables of this description afford an important summary of chemical facts: but the subject is too comprehensive and complex for them to have yet attained the precision and extent which science requires. For example, although the carbonic acid, No. 13, has a greater attraction for barytes than any of the other substances enumerated beneath it, yet it is not established how much greater this attraction is than that of the other substances mentioned. The difference of attraction might be expressed in numbers, but as the exact state and purity of each substance must be previously known, to render these numbers correct, the labour can only be accomplished in a long course of time; and even if this point were gained, something would still be wanting; for the quantities of bodies acting on each other, have often a material effect in modifying the effects produced.

Bergman furnished the ground-work of the following tables, Dr. Pearson enlarged and improved his labours, and they have been corrected according to recent discoveries. Though they extend only to the simplest cases of attraction, they form a valuable guide in conducting a variety of experiments and operations, and teach us to foretell results of which we should otherwise be uncertain, and might lose much time in discovering.

Those attractions which are said to take place in the *humid way*, require one of the substances at least to be in the fluid state; and therefore, as they take place through the medium of water, the temperature can but little exceed that of boiling water. Those attractions which take place in the *dry way*, or by fire, require one of the substances at least to be in the state of fusion.

Simple elective attractions.

No. 1. Caloric.

Oxygen,	Volatile Oils,
Ether,	Glass,
Alcohol,	Mercury,
Ammonia,	Bases of the gases.
Water,	

2. Oxygen.

In the humid way.	*In the dry way.*
Bases of the muriatic and other undecomposed acids,	Carbon,
	Zinc,
Carbon,	Iron,
Phosphorus,	Hydrogen,
Sulphur,	Manganese,
Light,	Cobalt,
Zinc,	Nickel,
Copper,	Lead,
Lead,	Tin,
Iron,	Phosphorus,
Silver,	Copper,
Platina,	Bismuth,
Mercury,	Antimony,
Gold,	Mercury at 600°
Nitrous gas,	Arsenic,
Muriatic acid,	Sugar,
Nitrous acid,	Sulphur,
Sulphuric acid,	Gold,
White oxide of manganese,	Silver,
Hydrogen,	Platina,
Volatile oils,	Mercury at above 1000°
Alcohol,	White oxide of manganese
Water.	

3. Sulphur.

Oxygen,	Oxygen,
Molybdic oxide and acid,	Potass,
Oxide of lead,	Soda,
.... tin,	Iron,
.... silver,	Copper,

SULPHUR (continued)

In the humid way.

Oxide of mercury,
.... arsenic,
.... antimony,
.... iron,
Fixed alkalies,
Barytes,
Strontian,
Lime,
Magnesia,
Phosphorus,
Fat oils,
Ammonia,
Ether,
Hydrogen gas.

In the dry way.

Tin,
Lead,
Silver,
Cobalt,
Nickel,
Bismuth,
Antimony,
Mercury,
Arsenic,
Uranium,
Molybdena,
Tellurium.

4. ALUMINE.

Acid, sulphuric,
.... nitric,
.... muriatic,
.... fluoric,
.... arsenic,
.... oxalic,
.... suberic,
.... tartaric,
.... succinic,
.... mucous,
.... citric,
.... phosphoric,
.... benzoic,
.... acetous,
.... boracic,
.... sulphurous,
.... nitrous,
.... carbonic,
.... prussic,
Potass,
Soda,
Barytes,
Strontian.

Acid, phosphoric,
.... boracic,
.... arsenic,
.... sulphuric,
.... nitric,
.... muriatic,
.... sebacic,
.... fluoric,
.... succinic,
.... lactic,
.... benzoic,
.... acetous,
Potass,
Soda,
Sulphur,
Oxide of lead.

5. Silex.

In the humid way.	*In the dry way*
Fluoric acid,	Potass,
Potass,	Soda,
Soda,	Phosphoric acid,
Barytes,	Oxide of lead.
Strontian.	

6. Magnesia.

Acid, oxalic,	Acid, phosphoric,
.... phosphoric,	.... boracic,
.... sulphuric,	.... arsenic,
.... fluoric,	.... sulphuric,
.... sebacic,	.... succinic,
.... arsenic,	.... fluoric,
.... mucous,	.... nitric,
.... succinic,	.... muriatic,
.... nitric,	.... suberic,
.... muriatic,	.... sebacic,
.... suberic,	.... lactic,
.... tartaric,	.... benzoic,
.... citric,	.... acetous,
.... lactic,	Fixed alkalies,
.... benzoic,	Sulphur,
.... acetous,	Oxide of lead.
.... boracic,	
.... sulphurous,	
.... carbonic,	
.... prussic,	
Sulphur.	

7. Lime.

Acid, oxalic,	Acid, phosphoric,
.... sulphuric,	.... boracic,
.... tartaric,	.... arsenic,
... succinic,	.... sulphuric,
.... phosphoric,	.... succinic,
.... mucous,	.... fluoric,
.... nitric,	.... nitric,

Simple elective attractions.

LIME (continued.)

In the humid way.	*In the dry way.*
Acid, muriatic	Acid, muriatic,
.... sebacic,	.... suberic,
.... suberic,	.... sebacic,
.... fluoric,	.... lactic,
.... arsenic,	.... benzoic,
.... citric,	.... acetous,
.... malic,	Fixed alkalies,
.... benzoic,	Sulphur,
.... acetous,	Oxide of lead.
.... boracic,	
.... sulphurous,	
.... nitrous,	
.... carbonic,	
.... prussic,	
Water,	
Fat oils,	
Sulphur,	
Phosphorus.	

8. BARYTES.

Acid, sulphuric,	Acid, phosphoric,
.... oxalic,	.... boracic,
.... succinic,	.... arsenic,
.... fluoric,	.... sulphuric,
.... phosphoric,	.... nitric,
.... mucous,	.... muriatic,
.... molybdic,	.... fluoric,
.... nitric,	.... sebacic,
.... muriatic,	.... succinic,
.... sebacic,	.... benzoic,
.... suberic,	.... acetous,
.... citric,	Fixed alkalies,
.... tartaric,	Sulphur,
.... arsenic,	Oxide of lead.
.... benzoic,	
.... acetous,	
.... boracic,	
.... sulphurous,	
.... nitrous,	
.... carbonic,	
.... prussic,	
Water.	

Barytes (continued.)

In the humid way.	*In the dry way.*
Fat oils,	
Sulphur,	
Sulphuretted hydrogen,	
Phosphorus.	

9. Potass.

Acid, sulphuric,	Acid, phosphoric,
.... nitric,	.... boracic,
.... muriatic,	.... arsenic,
.... sebacic,	.... sulphuric,
.... fluoric,	.... nitric,
.... phosphoric,	.... muriatic,
.... oxalic,	.... sebacic,
.... tartaric,	.... fluoric,
.... arsenic,	.... succinic,
.... succinic,	.... benzoic,
.... citric,	.... acetous,
.... benzoic	Barytes,
.... acetous,	Lime,
.... mucous,	Magnesia,
.... boracic,	Alumine,
.... sulphurous,	Silex,
.... nitrous,	Sulphur.
.... carbonic,	
.... prussic,	
Water,	
Fat oils,	
Sulphur,	
Metallic oxides.	

10. Soda and Ammonia.

Follow the same order as potass, both in the hum d and the dry way, except that with ammonia, the sulphuric acid comes first in both.

11. Sulphuric Acid.

Barytes,	Potass
Strontian,	Soda,

SULPHURIC ACID (continued.)

In the humid way.	*In the dry way.*
Potass,	Barytes,
Soda,	Strontian,
Lime,	Lime,
Magnesia,	Magnesia,
Ammonia,	Zircon,
Glucine,	Metallic oxides,
Yttria,	Ammonia,
Alumine,	Alumine.
Zircon,	
Metallic oxides,	
Water,	
Alcohol.	

12. NITROUS, NITRIC, MURIATIC, OXY-MURIATIC, AND NITRO-MURIATIC ACIDS.

Potass,	Barytes,
Soda,	Strontian,
Barytes,	Potass,
Strontian,	Soda,
Lime,	Lime,
Magnesia,	Magnesia,
Glucine,	Metallic oxides,
Yttria,	Ammonia,
Alumine,	Alumine.
Zircon,	
Metallic oxides,	
Water,	
Alcohol.	

13. CARBONIC ACID.

In the humid way.

Barytes,
Strontian,
Lime,
Potass,
Soda,
Magnesia,
Ammonia,
Alumine,

CARBONIC ACID (continued.)

In the humid way.

Metallic oxides,
Water,
Alcohol.

14. FLUORIC ACID.

In the humid way.	*In the dry way.*
Lime,	Lime,
Barytes,	Barytes.
Strontian,	Strontian,
Magnesia,	Magnesia,
Potass,	Alumine,
Soda,	Potass,
Ammonia,	Soda,
Glucine,	Metallic oxides,
Alumine,	Ammonia,
Zircon,	Alumine.
Metallic oxides,	
Silex,	
Water,	
Alcohol.	

N. B. In the *humid way*, the Boracic, the Arsenic, the Tungstic, the Oxalic, the Tartaric, and Phosphoric acids, follow the same order as the Fluoric, taking out *silex*.

In the *dry way*, the Boracic, the Arsenic, the Benzoic, the Phosphoric, and the Sebacic, follow the same order as the Fluoric.

15. MOLYBDIC ACID.	16. CHROMIC ACID.
In the humid way.	*In the humid way.*
Sulphur,	Potass,
Potass,	Soda,
Soda,	Oxide of lead,
The earths,	.... copper.
Metallic oxides.	

17. Acetous and Lactic Acids.

In the humid way.

Barytes,
Potass,
Soda,
Strontian,
Lime,
Ammonia,
Magnesia,
Metallic oxides,
Glucine,
Alumine,
Zircon,
Water,
Alcohol.

18. Succinic Acid.

In the humid way.

Barytes,
Lime,
Potass,
Soda,
Ammonia,
Magnesia,
Alumine,
Metallic oxides,
Water,
Alcohol.

N. B. The Citric and Benzoic acids follow the same order, except that lime should come before barytes; and for the Citric, zircon should be added after alumine.

19. Mucous Acid.

In the humid way.

Lime,
Barytes,
Magnesia,
Potass,
Soda,
Ammonia,
Alumine,
Metallic oxides,
Water,
Alcohol.

20. Prussic Acid.

In the humid way.

Potass,
Soda,
Ammonia,
Lime,
Barytes,
Strontian,
Magnesia,
Alumine,
Metallic oxides,
Water,
Alcohol.

21. Oxide of Platina.

In the humid way

Acid, gallic,
.... muriatic,
.... nitric.

22. Platina

In the dry way.

Arsenic,
Gold,
Copper,

Simple elective attractions.

OXIDE of PLATINA (continued)

In the humid way.

Acid, sulphuric,
.... arsenic,
.... fluoric,
.... tartaric,
.... phosphoric,
.... sebacic,
.... oxalic,
.... citric,
.... acetous,
.... succinic,
.... prussic,
.... carbonic,
Ammonia.

PLATINA (continued.)

In the dry way.

Tin,
Bismuth,
Zinc,
Antimony,
Nickel,
Cobalt,
Manganese,
Iron,
Lead,
Silver,
Mercury,
Alkaline sulphurets.

23. OXIDE OF GOLD.

Acid, gallic,
.... muriatic,
.... nitric,
.... sulphuric,
.... arsenic,
.... fluoric,
.... tartaric,
.... phosphoric,
.... acetous,
.... sebacic,
.... prussic,
Fixed alkalies,
Ammonia,
Sulphuretted hydrogen.

24. GOLD.

Mercury,
Copper,
Silver,
Lead,
Bismuth,
Tin,
Antimony,
Iron,
Platina,
Zinc,
Nickel,
Arsenic,
Cobalt,
Manganese,
Alkaline sulphurets.

25. OXIDE OF MERCURY.

Acid, sebacic,
.... gallic,
.... muriatic,
.... oxalic,
.... succinic,
.... phosphoric,
.... sulphuric,
.... mucous,

26. MERCURY.

Gold,
Silver,
Platina,
Lead,
Tin,
Zinc,
Bismuth,
Copper,

Simple elective attractions.

OXIDE OF MERCURY (continued.)	MERCURY (continued.)
In the humid way.	*In the dry way.*
Acid, tartaric,	Antimony,
.... citric,	Arsenic,
.... malic,	Iron,
.... sulphurous,	Alkaline sulphurets
.... nitric,	Sulphur.
.... fluoric,	
.... acetous,	
.... benzoic,	
.... boracic,	
.... prussic,	
.... carbonic,	
Ammonia.	

27. OXIDE OF LEAD.	28. LEAD.
Acid gallic,	Gold,
.... sulphuric,	Silver,
.... sebacic,	Copper,
.... mucous,	Mercury,
.... oxalic,	Bismuth,
.... arsenic,	Tin,
.... tartaric,	Antimony,
.... phosphoric,	Platina,
.... muriatic,	Arsenic,
.... sulphurous,	Zinc,
.... suberic,	Nickel,
.... nitric,	Iron,
.... fluoric,	Alkaline sulphurets,
.... citric,	Sulphur.
.... malic,	
.... succinic,	
.... acetous,	
.... benzoic,	
.... boracic,	
.... prussic,	
.... carbonic,	
Fixed alkalies,	
Fat oils,	
Ammonia.	

29. Oxide of Silver.

In the humid way.

Acid, gallic,
.... muriatic,
.... sebacic,
.... oxalic,
.... sulphuric,
.... mucous,
.... phosphoric,
.... sulphurous,
.... nitric,
.... arsenic,
.... fluoric,
.... tartaric,
.... citric,
.... succinic,
.... acetous,
.... prussic,
.... carbonic,
Ammonia.

30. Silver.

In the dry way.

Lead,
Copper,
Mercury,
Bismuth,
Tin,
Gold,
Antimony,
Iron,
Manganese,
Zinc,
Arsenic,
Nickel,
Platina,
Alkaline sulphurets.

31. Oxide of Nickel.

Acid, oxalic,
.... muriatic,
.... sulphuric,
.... tartaric,
.... nitric,
.... sebacic,
.... phosphoric,
.... fluoric,
.... mucous,
.... succinic,
.... citric,
.... acetous,
.... arsenic,
.... boracic,
.... prussic,
.... carbonic,
Ammonia.

22. Nickel.

Iron,
Cobalt,
Arsenic,
Copper,
Gold,
Tin,
Antimony,
Platina,
Bismuth,
Lead,
Silver,
Zinc,
Alkaline sulphurets,
Sulphur.

Simple elective attractions.

33. Oxide of Copper.	34. Copper.
In the humid way.	*In the dry way.*
Acid, gallic,	Gold,
.... oxalic,	Silver,
.... tartaric,	Iron,
.... muriatic,	Arsenic,
.... sulphuric,	Manganese,
.... mucous,	Zinc,
.... nitric,	Antimony,
.... sebacic,	Platina,
.... arsenic,	Tin,
.... phosphoric,	Lead,
.... succinic,	Nickel,
.... fluoric,	Bismuth,
.... citric,	Cobalt,
.... acetous,	Mercury,
.... boracic,	Alkaline sulphurets,
.... prussic,	Sulphur.
.... carbonic,	
Potass,	
Soda,	
Ammonia,	
Salts,	
Fat oils.	

35. Oxide of iron.	36. Iron.
Acid, gallic,	Nickel,
.... oxalic,	Cobalt,
.... tartaric,	Manganese,
.... camphoric,	Arsenic,
.... sulphuric,	Copper,
.... mucous,	Gold,
.... muriatic,	Silver,
.... nitric,	Tin,
.... suberic,	Antimony,
.... phosphoric,	Platina,
.... arsenic,	Bismuth,
.... fluoric,	Lead,
.... succinic,	Alkaline sulphurets,
.... citric,	Sulphur.
.... acetous,	

OXIDE OF IRON (continued.)

In the humid way.	*In the dry way.*
Acid, boracic,	
.... prussic,	
.... carbonic.	

37. OXIDE OF TIN.

Acid, gallic,
.... sebacic,
.... tartaric,
.... muriatic,
.... sulphuric,
.... oxalic,
.... arsenic,
.... phosphoric,
.... nitric,
.... succinic,
.... fluoric,
.... mucous,
.... citric,
.... acetous,
.... boracic,
.... prussic,
Potass,
Soda,
Ammonia.

38. TIN.

Zinc,
Mercury,
Copper,
Antimony,
Gold,
Silver,
Lead,
Iron,
Manganese,
Nickel,
Arsenic,
Platina,
Bismuth,
Cobalt,
Alkaline sulphurets
Sulphur.

39. ZINC.

Acid, gallic,
.... oxalic,
.... sulphuric,
.... muriatic.
.... mucous,
.... nitric,
.... sebacic,
.... tartaric,
.... phosphoric,
.... citric,
.... succinic
.... fluoric,
.... arsenic,

40. ZINC.

Copper,
Antimony,
Tin,
Mercury,
Silver,
Gold,
Cobalt,
Arsenic,
Platina,
Bismuth,
Lead,
Nickel,
Iron.

ZINC (continued.)

In the humid way.	*In the dry*
Acid, acetous,	
.... boracic,	
.... prussic,	
.... carbonic,	
Fixed alkalies,	
Ammonia.	

41. OXIDE OF BISMUTH.	42. BISMUTH.
Acid, oxalic,	Lead,
.... arsenic,	Silver,
.... tartaric,	Gold,
.... phosphoric,	Mercury,
.... sulphuric,	Antimony,
.... sebacic,	Tin,
.... muriatic,	Copper,
.... nitric,	Platina,
.... fluoric,	Nickel,
.... mucous,	Iron,
.... succinic,	Zinc,
.... citric,	Alkaline sulphurets,
.... acetous,	Sulphur.
.... prussic,	
.... carbonic,	
Ammonia.	

43. OXIDE OF ARSENIC.	44. ARSENIC
Acid, gallic,	Nickel,
.... muriatic,	Cobalt,
.... oxalic,	Copper,
.... sulphuric,	Iron,
.... nitric,	Silver,
.... sebacic,	Tin,
.... tartaric,	Lead,
.... phosphoric,	Gold,
.... fluoric,	Platina,
.... mucous,	Zinc,
.... succinic,	Antimony,
.... citric,	Alkaline sulphurets,
.... arsenic,	Sulphur.

OXIDE OF ARSENIC (continued.)

In the humid way.

Acid, acetous,
.... prussic,
Fixed alkalies,
Ammonia,
Fixed oils,
Water.

In the dry way.

45. OXIDE OF ANTIMONY.

Acid, gallic,
.... sebacic,
.... muriatic,
.... benzoic,
.... oxalic,
.... sulphuric,
.... nitric,
.... tartaric,
.... mucous,
.... phosphoric,
.... citric,
.... succinic,
.... fluoric,
.... arsenic,
.... acetous,
.... boracic,
.... prussic,
.... carbonic,
Sulphur,
Fixed alkalies,
Ammonia.

46. ANTIMONY.

Iron,
Copper,
Tin,
Lead,
Nickel,
Silver,
Bismuth,
Zinc,
Gold,
Platina,
Mercury,
Arsenic,
Cobalt,
Alkaline sulphurets,
Sulphur.

47. FIXED OILS.

In the humid way.

Barytes,
Strontian,
Lime,
Ether,
Volatile oils,
Potass,
Soda,

48. VOLATILE OILS.

In the humid way.

Ether,
Alcohol,
Fixed oils,
Fixed alkalies,
Sulphur,
Phosphorus.

Fixed Oils (continued.)

In the humid way.	*In the humid way.*
Magnesia,	
Ammonia,	
Oxide of mercury,	
Other metallic oxides,	
Alumine,	
Sulphur,	
Phosphorus.	

49. Alcohol.	50. Ether
Water,	Alcohol,
Ether,	Volatile oils,
Volatile oils,	Water,
Ammonia,	Sulphur,
Fixed alkalies,	Phosphorus,
Alkaline sulphurets,	Caoutchouc.
Sulphur,	
Muriates,	
Phosphoric acid.	

The preceding tables illustrate cases of simple affinity with respect to substances of the most frequent recurrence; a few words will suffice to explain their application. If it be required to decompose an aqueous solution of muriate of soda, the first inquiry is, whether the acid or the soda is to be set at liberty. If the acid, then find a substance whose affinity for soda is greater than that of muriatic acid, and turning to the first column of No. 9, which shews the affinities of soda in the humid way, the substances sulphuric and nitric acid stand above the muriatic; the addition then of either of these to the given solution, will decompose the salt, and the acid will be obtained in a disengaged state.—If the soda be wanted, turn to the first column of No. 12, exhibiting the affinities of the muriatic acid in the humid way, and it will be found that the affinity of potass for that acid is greater than that of soda; hence by using potass the soda will be set free.

Citrate of lime affords an example of a case a little different to the above: if this compound is to be decomposed, we find from No. 18, that it cannot be done so as to set at liberty the lime, because, (from the remark subjoined to that table,) it

appears that lime, for a table of the citric acid, would be first in the column, as it has a greater affinity for that acid than any other substance; but from No. 7, in the first column of lime, it may be seen that no less than twelve acids will each of them separate the lime so as to leave the citric acid at liberty. The lime, however, may be separated by another process: suppose, for instance, that muriatic acid has been employed to precipitate the citric acid, and the muriate of lime thus formed be removed into another vessel, then by referring to No. 12, it appears that there are four substances that have a greater affinity for muriatic acid than lime, and therefore any one of them will join the acid and disengage the lime.

The columns exhibiting affinities in the dry way, are in their construction similar to the other, that is, the substances enumerated are placed according to the strength of their attraction for the substance at the head of each, but in other respects they are to be considered as perfectly distinct; although their situation in the present arrangement, affords an opportunity for comparisons, which it may in several instances be interesting to make. The affinities which take place among bodies in fusion, differ from those in the humid way, by their not affording precipitates; therefore when the bodies in this way presented to each other, are perfect fluids, there is no separation of their component parts.

Bergman has adopted a symbolical mode of representing affinities: supposing magnesia to be presented to a solution of sulphate of potass, no decomposition will follow, and he would state the case thus:

Sulphate of potass	{ Potass	
	{ Sulphuric acid	Magnesia.

In this scheme, the sulphate of potass is connected by a vertical bracket with its two component parts—potass and sulphuric acid. Horizontally opposite the sulphuric acid is placed magnesia, to denote that it is presented to that acid, with which it is not connected by a bracket, because the magnesia and sulphuric acid do not unite, magnesia not having the power to decompose sulphate of potass. But in a case where decomposition ensues, the representation would have been delineated in the following manner:

Magnesia

Sulphate of magnesia { Magnesia / Sulphuric acid — Potass

Sulphate of potass.

Here the bracket under the sulphuric acid and potass denotes, that these two substances unite, and form the compound written under it, viz. sulphate of potass. The point of the bracket is turned up, to denote that the compound remains in solution. The magnesia is disengaged, and half a bracket with the point downward, is placed over it, to denote that it falls to the bottom, or is precipitated.

The following is an example of the expression of compound affinities:

Muriate of potass

Sulphate of potass { Potass — 32 Muriatic acid

62 + 23 = 85

Sulphuric acid 54 Lime

86 } Muriate of lime

Sulphate of lime

The attraction between the potass and sulphuric acid is expressed by the number 62; and the attraction between the muriatic acid and lime is expressed by the number 23. The sum of these numbers, viz. 85, expresses the tendency to preserve the original forms of sulphate of potass and muriate of lime. On the other hand, the attraction between the potass and muriatic acid is expressed by 32, and the attraction between sulphuric acid and lime by 54. The sum of these numbers is 86, which expresses the force tending to decomposition, and as it exceeds the force of composition, the double decomposition will take place.

The numerical expression of affinities has been attempted by Morveau, in the following table, with respect to the alkalies, three of the earths, and the five principal acids. By this means, the comparative force of the attractions of the bodies

concerned are indicated, and the assistance afforded as to the probability of any particular decomposition, is materially greater than the tables we have already given will afford. It is by tables of this kind only that compound attractions can be developed.

Numerical Expression of Affinities.

	Sulphuric acid.	Nitrous acid.	Muriatic acid.	Acetous acid.	Carbonic acid.
Barytes	66	62	36	29	14
Potass	62	58	32	26	9
Soda	58	50	31	25	8
Lime	54	44	23	19	12
Ammonia ..	46	38	21	20	4
Magnesia ..	50	40	22	17	6
Alumine ...	40	36	18	15	2

DYEING.

Dyeing is the art of communicating colours to the various stuffs used in clothing.

The object which the dyer has in view, is to give stuffs a uniform and durable colour, at the same time that he entirely preserves their original texture. He therefore uses colours in solution, in order that their particles may apply themselves to the individual fibres of the stuff, according to their affinity for it. When, for example, a quantity of wool, freed from all impurity, is dipped into the solution of any colouring matter, if the fibres of the wool have a stronger attraction for the colouring matter than the water or other menstruum which holds that colour in solution, the colouring matter will leave its solvent, and apply itself to the wood, which will by that means be dyed; its fibres will have become covered with the colouring matter; and if their attraction for it be so strong, that the action of soap, air, and light, or other ordinary means of exposure, shall have no perceptible effect in decomposing the combination, or, in other words, of injuring its tinge, the colour is said to be permanent.

It may happen, however, and in dyeing it generally happens, that the colouring matter which it is desirable to employ, has either no attraction, or but a very weak attraction, for the fibres of the stuff to be dyed. In this case, it is necessary to employ a third substance, which has a strong attraction both for the colouring matter and the stuff, and which consequently becomes the intermedium by which the dye is fixed upon the fibres of the stuff: the substance or intermedium thus used is called a *mordant*.

Dyes of the first class, or those which require no mordant, are called *permanent* or *great* dyes. Indigo and woad are the only substances in use of this description.

Dyes of the second class, or those which require a mordant to fix them, are called *false* or *little* dyes. Another mode of denominating the difference, is to call the former class *substantive*, and the latter *adjective* colours; and these terms, after the example of Bancroft, are not uncommonly used.

The most usual stuffs or materials which are required to be dyed, are wool, silk, cotton, and linen. Each of these sub-

stances requires some difference in its mode of treatment, to which we shall advert, after a few remarks with respect to mordants, and observing also that the terms *cloth*, and *stuff*, will be used as general terms for all materials subjected to dyeing.

Mordants.

The substances most usually employed as mordants, are earths, metallic oxides, the astringent parts of vegetables, and fixed oils. That the earths are essentially the same as metallic oxides, cannot be doubted; but it here answers the purpose of perspicuity, to mention them separately.

Alumine is the most important and generally used of all the earthy mordants. Its attraction for the animal substances, wool and silk, is very strong, but it is only weak for the vegetable substances, cotton and linen. Its attraction for vegetables seems to be almost entirely confined to their colouring matter. It is not used in its simplest state, but in that of a *sulphate* or *acetate*.

Alum, which is the sulphate of alumine and potass, when used as a mordant, is dissolved in water, and very frequently a quantity of tartar (super-tartrate of potass) is dissolved along with it. Into this solution is put the cloth, and kept in it till it has absorbed as much alumine as may be necessary. It is then taken out, and for the most part washed and dried. The tartar serves two purposes; the potass it contains combines with the sulphuric acid of the alum, and thus prevents that powerful acid from injuring the texture of the cloth; and the tartaric acid, combining with part of the alumine, forms a tartrate of alumine, which is more easily decomposed by the stuff than alum.

Acetate of alumine is chiefly employed for cotton and linen; they derive from it a greater quantity of alumine than they would from alum, and consequently afford more permanent and finer colours. This mordant is prepared by pouring acetate of lead into a solution of alum; in the proportion of one part of the acetate of lead to three of the alum by weight, with a sixteenth of potass, and as much powdered chalk; the sulphuric acid and lead form an insoluble precipitate, while the alumine and acetic acid remain combined in the solution. The chalk and potass combine with the excess of acid.

Lime has a strong attraction for cloth, and may therefore be employed as a mordant; but it renders colours dull. When used, it is either in the state of lime-water, or of sulphate of lime dissolved in water.

Metallic oxides have in general a strong attraction for colouring matters and for animal substances; but the only oxides which are extensively used by the dyer, are those of tin and iron. Each of these metals may be used at two degrees of oxidizement; the second oxide of each is in tin white, and in iron red, and as the oxides with a less proportion of oxygen than these are not permanent, but are respectively converted into the white and red, merely by exposure to the air, or in the course of the process for using them, we may consider the white and red oxides as the only oxides of these metals which are employed.

Tin is used as a mordant in three states; dissolved in nitro-muriatic acid, in acetous acid, and in a mixture of sulphuric and nitric acid. Nitro-muriate of tin is the mordant most commonly employed. The mode in which it is prepared is given at page 389, of this volume. The tin employed is about one-eighth of the weight of the acid. It demands experience and care to manage the solution well; a particular state of the acid, not perfectly understood, appears to be required. The solution should be of a bright yellow; if it become milky, which it sometimes does, it is unfit for use. It is a general precaution not to use the acid, which is called *dyer's aqua-fortis*, till it has been kept at least a year. The nitro-muriate of tin is largely diluted with water, the cloth is then dipped into it, and allowed to remain till saturated, after which it is washed and dried. Tartar is generally added to the solution, for much the same reason that it is added to the mordant of alumine, prepared with alum.

Dr. Bancroft recommends a mixture of sulphuric and muriatic acid as a mordant for wool; it is cheaper than the nitro-muriate, and is equally as efficacious. One part of tin, two of sulphuric acid, and three of muriatic acid, may be employed.

Haussman considers the acetate of tin preferable to the nitro-muriate, in the dyeing of cotton and linen. He prepares it by mixing acetate of lead and nitro-muriate of tin.

The strong affinity of the red oxide of iron for cloth is evinced by the fixedness of the spots called iron-moulds, which appear rather to brighten than otherwise under the ordinary course of washing. Iron is employed either in the state of a sulphate or acetate; the sulphate dissolved in water is commonly used for wool; for other substances, the acetate is preferred. It is prepared by dissolving iron in vinegar or alegar, and is not ready for use in less than six weeks or two months.

The astringent vegetables most commonly employed are nut-galls and sumach; tannin, which is supposed to be the same with the astringent principle, has a strong affinity for cloth, and for several colouring matters. The cloth is prepared for dyeing, by dipping it in an infusion of the astringent. Mordants of this class are mostly used for grave colours.

Oil is used as a mordant in dyeing cotton and linen a fine red: their fibres being covered with a thin stratum of it, are then in a state to attract alumine, by which the colour is received. Several other substances are also employed, which, like oil, are thus found useful as intermediates, although the mode of their action is not always apparent. Tartar and common salt have already been mentioned; acetate of lead, muriate of ammonia, sulphate of copper, acetate of copper, and many other substances, might be added to the number. They are used frequently only to change the shade of the colour.

Dyeing is completely a chemical art; all its effects are produced by the operation of affinities or attractions, and a knowledge of these must be derived from chemistry. Berthollet thus treats of the action of mordants:

Metallic colours must be distinguished from those which are peculiar to vegetable and animal substances.

The colours of vegetables are modified and changed by oxidation, according to the degree to which it is carried.

Vegetable and animal substances may themselves possess a peculiar colour, which varies in the different states through which they pass; or they may owe their colours to tinging particles, either combined or simply mixed with them. These are the particles extracted from different substances, and which undergo different preparations, to fit them for the purposes of dyeing.

The colouring particles have chemical properties which distinguish them from all other substances: the attractions which they have for acids, alkalies, earths, metallic oxides, oxygen, and cloth, constitute the chief of these properties.

According to the attraction which the colouring particles have for wool, silk, cotton, or linen, they unite more or less readily, and more or less intimately, with each of these substances, and thence arises the first cause of variation in the processes employed.

By the attraction which the colouring particles have for alumine and metallic oxides, they form compounds with these substances, in which their colour is more or less modified, becomes more fixed, and more difficultly affected by external

agents than before. This compound being formed of principles, which have separately the power of uniting with vege table substances, and more especially with animal substances, preserves this property, and forms a triple compound with the cloth; and the colour, which has been again modified by the formation of this triple union, acquires a greater degree of fixity, and of indestructibility by external agents. The colouring particles have frequently so great an attraction for alumine and metallic oxides, that they separate them from acids which held them in solution, and fall down with them; but the attraction of the stuff is sometimes necessary, in order to produce this separation.

The metallic oxides which combine with the colouring particles, modify their colours, not only by their own, but also by acting upon their composition by means of their oxygen. The change which the colouring particles thus suffer, is similar to that occasioned by the air, which injures all colours more or less.

Of the principles which compose the atmosphere, it is only the oxygen which acts upon the colouring particles; it combines with them, and weakens their colour; but its action is principally exerted on the hydrogen which enters into their composition, and with which it forms water. This change, which in effect is a species of combustion, renders the charcoal which enters into the composition of the colouring particles predominant, and the colour commonly changes to yellow, fawn-colour, or brown; or the injured part, by uniting with what remains of the original colour, produces other appearances.

Light favours the combination of the colouring particles, which frequently cannot take place without its aid; and it is thus that it contributes to the destruction of colours. Heat promotes it also, but less powerfully than light, unless it has a certain degree of intensity. To a similar combustion are to be attributed the effects of the pale nitric acid, of the oxymuriatic acid, and even of the sulphuric acid, when they make the colours of substances pass to a yellow, and even to a black. The effects of combustion may, however, be concealed by the oxygen combining with the colouring particles, without acting particularly on the hydrogen.

Colours are more or less durable, or more or less fixed, according to the greater or less disposition of the colouring particles to undergo combustion, and to allow it to go on to a more or less advanced state.

Some substances are also capable of acting on the colour of cloth, by a superiority of attraction, or by a solvent power;

and in this consists the *usual* action of acids, alkalies, and soap. A small quantity of these agents, however, may sometimes form supra-compounds with the cloth, and thereby change its colour.

Metallic oxides produce, in the colouring particles with which they unite, a degree of combustion proportioned to the quantity of oxygen which can be taken from them by these particles. The colours which the compounds of metallic oxides and colouring particles assume, are therefore the product of the colour peculiar to the colouring particles, and of that peculiar to the metallic oxide; but the colouring particles and metallic oxides must be considered in that state to which they have been reduced by the diminution of oxygen in the oxide, and the diminution of hydrogen in the colouring particles. Hence it follows,

1st, That the metallic oxides to which the oxygen is only slightly attached, are not fit to serve as connecting mediums for the colouring particles, because they produce in them too great a degree of combination; such are the oxides of silver, gold, and mercury.

2d, That the oxides which undergo considerable changes of colour, by giving off more or less of their oxygen, are also bad intermediums, especially for light shades, because they produce changeable colours; such are the oxides of copper, of lead, and of bismuth.

3d, That the oxides which strongly retain their oxygen, and suffer very little change of colour by the loss of a part of it, are best fitted to answer this purpose; such is particularly the oxide of tin, which quits the menstruum easily, which has a strong attraction for the colouring particles, and which affords them a basis that is very white, and proper for giving a brightness to their shades, without altering them by the admixture of another colour. The oxide of zinc possesses some of these qualities.

In order to account for the colours which result from the union of colouring particles, with the basis which a mordant gives them, we must attend to the proportion in which the colouring particles unite to that basis; thus the solution of tin, which produces a very copious precipitate with a solution of colouring particles, and thereby proves that the oxide of tin enters in a large proportion into the precipitate, has a much greater influence on the colour of the precipitate, by the whiteness of its basis, than the solution of zinc, or that of alum, both of which generally produce much less copious precipitates. The precipitates produced by these two last substances retain very nearly the natural tint of the colouring particles. We must

then distinguish, in the action of mordants, the combinations that may take place by their means, between the colouring particles, the stuff, and the intermedium; the proportions of the colouring substance and intermedium; the modifications of colour, which may arise from the mixture of the colour of the colouring particles, and of that of the basis to which they are united; and finally, the changes which the colouring particles may suffer from the combustion that may be produced by the intermedium.

Astringents do not derive their characteristic property from an acid, or from any other individual principle which is always the same, but from the property which they possess of uniting with the oxide of iron, of reducing it to a state of black oxide, and of acquiring themselves a dark colour, by the combustion they experience. Galls, which may be considered as representing all astringents, readily undergo a slight combustion, which gives them a deep brown colour; but this combustion, which requires but a small quantity of oxygen, soon ceases without injuring their properties. Galls owe their stability to the large proportion of carbon they contain; and as they have the property of combining with some vegetable substances, with several colouring matters, and particularly with animal substances, they serve as an intermedium for them, and impart to them their own firmness of colour.

Of the Preparation required by Wool for Dyeing.

Wool is composed of fine, elastic filaments; the most powerful microscope discovers no asperity on their surface: but if one of them be gently pressed between two fingers while it is drawn from between them with the other hand, so as to cause the fingers to glide towards its root, a slight resistance to the motion may easily be perceived; if the motion be from the root to the other extremity, not the slightest resistance occurs. Hence it is inferred, that the surface of every hair is bearded like a head of barley, or covered with lamina lying one over another like the scales of a fish; and it is from this property that we acquire all the advantages of felting; for when the fibres are subjected to motion, as woollen cloths in the fulling-mill, or fur under the bowstring of the hatter, they lock into and become intertwisted among each other; the stuff contracts in length and breadth, but increases in thickness and solidity, and will not unravel when it is cut. As this conformation of the fibres is a disadvantage in the operation of combing and spinning, the wool is oiled, in order to lessen its asperity, and make it work

more freely. But as this coating of oil must be removed before the wool can be properly dyed, the yarn, or manufactured goods, are taken to the fulling mill, where they are beaten with large beetles, in troughs of water mixed with fuller's earth: the clay renders the oil soluble in water, the plentiful addition and change of which, leaves the goods completely scoured.

Wool is naturally covered with a kind of oil, and when it is dyed in the fleece, this oil must be removed, which is usually done by heating it in a kettle of water containing a fourth of putrid urine, and afterwards washing it in a running stream. In this case it is the volatile alkali of the urine which renders the oil of the wool miscible with water.

Wool, fur, and hair, have precisely the same texture and chemical composition; but hair is usually drier, harder, and in thicker filaments, than wool or fur.

To dye Wool Blue.

The only colouring matters used in dyeing wool blue, are woad and indigo, which are both substantive colours, that is, they are permanent without requiring a mordant. Woad alone will not give a deep blue, but when it is mixed with indigo, a very rich colour is obtained. The strongest kind of woad is called *pastel*. Quatremere recommends the following mode of preparing a blue vat: Into a vat about seven and a half feet deep, and five and a half broad, are thrown two balls of woad, weighing together about 400 pounds, first breaking them; thirty pounds of weld are boiled in a copper for three hours, in a sufficient quantity of water to fill the vat; when this decoction is made, twenty pounds of madder and a basket full of bran are added, and it is boiled half an hour longer. This bath is cooled with twenty buckets of water; and after it is settled, the weld is taken out, and it is poured into the vat; all the time it is running in, and for a quarter of an hour after, it is to be stirred with a rake. The vat is then covered up very hot, and left to stand six hours, when it is raked again for half an hour, and this operation is repeated every three hours. When blue veins appear on the surface of the vat, eight or nine pounds of quicklime are thrown in. Immediately after the lime, or along with it, the indigo is put into the vat, being first ground fine in a mill with the least possible quantity of water, (it is now usually ground dry.) When it is diluted to the consistence of a thick pap, it is drawn off at the lower part of the mill, and thrown thus into the vat. The quantity of indigo depends upon the shade of colour required. From

ten to thirty pounds must therefore be put to the vat now described, according to the occasion.

If, on stiking the vat with the rake, a fine blue scum arises, it is fit for use, after being stirred twice with the rake in six hours to mix the ingredients. Great care should be taken not to expose the vat to the air, except when stirring it. As soon as that operation is over, the vat is covered with a wooden lid, on which are spread thick cloths, to retain the heat as much as possible. Notwithstanding this care, the heat is so much diminished at the end of eight or ten days, that the liquor must be re-heated, by pouring the greater part of it into a copper over a large fire: when it is hot enough, it is returned into the vat, and covered as before.

This vat is liable to two inconveniences, first, it runs sometimes into the putrefactive fermentation, which is known by the fetid odour it exhales, and by the reddish colour it assumes. This accident is remedied by adding more lime. The vat is then raked; after two hours lime is put in, the raking performed again, and these operations are repeated till the vat is recovered; secondly, if too much lime is added, the necessary fermentation is retarded; this is remedied by putting in more bran or madder, or a basket or two of fresh woad.

When cloth is to be dyed, the vat is raked two hours before the operation, and to prevent it from coming in contact with the sediment, which would cause inequalities in the colour, a kind of lattice of large cords, caled a cross, is introduced; when unmanufactured wool is to be dyed, a net with small meshes is placed over this. The wool or cloth being thoroughly wetted with lukewarm water, is pressed out, and dipped into the vat, where it is moved about a longer or shorter time, according as the colour is intended to be more or less deep, taking it out occasionally, to expose it to the air, the action of which is necessary to change the green colour, given the stuff by the bath, to a blue. Woollen and cloth dyed in this manner ought to be carefully washed, to carry off the loose colouring matter; and when they are of a deep hue, soap should be used, as it will only cleanse and not injure the colour. The more perfectly the wool has been scoured, the better it will receive the dye.

A vat which contains no woad, is called an indigo-vat. For this vat, the indigo is rendered soluble in water by potash instead of lime; a copper vessel is used, and six pounds of potash, twelve ounces of madder, and six pounds of bran, are boiled with every 120 gallons of water; six pounds of finely ground indigo are then added, and after carefully raking it,

the vat is covered, and a slow fire kept round it. Twelve hours afterwards it is to be raked a second time, and this operation is to be repeated at similar intervals of time, till the dye becomes blue, which will generally happen in forty-eight hours. If the bath be properly managed, it will be of a green colour, covered with coppery scales, and a fine blue scum.

The dye called *saxon blue*, is made with the solution of indigo in sulphuric acid. Take four parts of sulphuric acid, and pour them on one part of indigo in fine powder: let the mixture be stirred for some time, and after it has stood twenty-four hours, add one part of dry potash; let the whole be again well stirred, and after it has stood a day and a night, add gradually more or less water. The cloth to be dyed must be prepared with tartar and alum, and more or less indigo must be put into the bath, according to the shade required. For deep shades, also, the cloth must be passed several times through the bath: light shades may be dyed after deep ones, but they will not have the lustre given by a fresh bath.

To dye Wool Red.

Reds are a very important class of colours, and are furnished by a great number of substances. They all depend, either for their fixedness or beauty, upon the use of mordants: the principal of them are, kermes, cochineal, archil, madder, carthamus, and Brazil-wood. Kermes and cochineal are the female of two different insects, archil is a species of lichen or moss, the colour of which has been heightened by urine and quicklime; madder is a root, carthamus a flower, and Brazil-wood the trunk or ligneous part of a tree of that name. Pewter boilers, or well tinned copper, must be used in preparing all red baths.

The shades of red are usually distinguished into three classes; viz. the madder red, crimson, and scarlet. Madder is employed for coarse goods. It gives out its colour to water, and the bath prepared with it is not made hotter than what the hand can bear, until the wool has been in it about an hour, when it may be boiled for a few minutes just before the wool is taken out. It may be used in the proportion of one-third or one-fourth of the wool dyed. Cloths are prepared for the madder-bath by boiling them for two or three hours in a solution of alum and tartar; after having been taken out of which, they are left to drain for a few days in a cool place before they are dyed. The use of archil gives a fine but transient bloom to the madder dye. Archil and Brazil-wood, from their

perishableness, are seldom used to wool except in this way as auxiliaries.

When sulphate of copper is employed as the mordant, madder dyes a clear brown, inclining to yellow. Tin brightens its colour, but not materially.

Kermes has not been much used since the art of brightening cochineal with tin was discovered, as it has not so fine a bloom as the latter dye, though it possesses greater durability. Kermes imparts its colour to water, and the quantity of it used is, for a full colour, at least three-fourths of the weight of the wool employed. The wool is put in at the first boiling, after having been previously prepared by boiling it for half an hour in water with bran, and afterwards two hours in another bath with one-tenth of tartar dissolved in sour water, and then leaving it for a few days in a linen bag.

The red colour of the flowers of carthamus is extracted by a weak alkaline ley, and precipitated by lemon juice, or sulphuric acid, but is chiefly used for silk and cotton. The precipitate is used in dyeing, and is called *safflower*, or *bastard saffron*.

A crimson colour inclining to violet, is the natural colour of cochineal, which yields most of its colouring matter to water, and by the addition of a little alkali or tartar, the whole of it is extracted. To dye crimson, by a single process, a solution of two ounces and a half of alum, and an ounce and a half of tartar, with an ounce of cochineal, are employed for every pound of stuff. A little nitro-muriate of tin must be added for a fine crimson; archil gives to crimsons that fine dark shade which is called bloom, but this soon disappears by exposure to the air and light. For pale crimsons the quantity of cochineal is reduced, and madder substituted.

Dr. Bancroft first suggested that scarlet was a compound of crimson and yellow, and he founded upon this idea a more economical mode of producing it than had previously been used; he gives the following directions for dyeing scarlet: A hundred pounds of cloth are to be put into a tin vessel, nearly filled with water, with which about eight pounds of the muriosulphuric solution of tin have been previously mixed. The liquor is made to boil, and the cloth is turned through it by the winch for a quarter of an hour in the usual manner. The cloth is then taken out, and four pounds of cochineal, with two pounds and a half of quercitron-bark in powder, put into the bath, and well mixed. The cloth is then returned into the liquor, which is made to boil, and the operation is continued as usual, till the colour be duly raised, and the dyeing liquor exhausted, which will usually happen in about fifteen

or twenty minutes; after which the cloth may be taken out and rinsed. In this method, the labour and fuel necessary in the common process for the second bath are saved; the operation is finished in much less time; all the tartar will be saved, as well as two-thirds of the expense of the solvent for the tin, and at least one-fourth of the cochineal usually required; the colour at the same time will not be in any respect inferior to that produced in the ordinary way, at so much more trouble and expense; and it will even look better by candle-light than others.

By omitting the quercitron-bark, the above process will afford a rose-colour.

Scarlet may be changed to crimson, by boiling the cloth in a solution of alum, till the shade desired is obtained; alkalies and earthy salts in general have the same effect as alum.

The murio-sulphuric solution of tin here directed to be used, is prepared by mixing two pounds of sulphuric acid with three pounds of muriatic acid, pouring them upon fourteen ounces of granulated tin. Heat must be applied to hasten the solution.

To dye Wool Yellow.

Weld, fustic, and quercitron-bark furnish the best yellows:—weld is a plant which is both cultivated and grows wild in this country; the stem is slender, and rises to the height of three or four feet; the entire plant is used in dyeing, and is gathered when it is ripe: the shortest and slenderest stems are the most esteemed. Fustic is the wood of a large West Indian tree. Quercitron is a species of oak, which grows in North America, and is there called yellow oak; its bark is the only part of it used in dyeing.

The colours obtained from weld and quercitron-bark nearly resemble each other in shade, and also in durability, which is not great: but the bark containing the largest quantity of colouring matter, it is not only the most convenient to use, but upon the whole the cheapest: Dr. Bancroft has given the best directions for its use; he directs a deep and lively yellow to be thus prepared for wool: let the cloth be boiled for an hour or more, with about one-sixth of its weight of alum, dissolved in a sufficient quantity of water; then plunge it, without rinsing, into a bath of warm water, containing in it as much quercitron-bark as equals the weight of the alum employed as a mordant. The cloth is to be turned through the boiling liquid till it has acquired the intended colour. Then a quantity of clean powdered chalk, equal to the hundredth part of the weight of the cloth, is to be stirred in, and the opera-

tion of dyeing is to be continued for eight or ten minutes longer.

For bright orange yellow, put for every ten parts of cloth, one part of bark into a sufficient quantity of hot water; after a few minutes, an equal quantity of murio-sulphate of tin is to be added, and the mixture well stirred. The cloth acquires the colour in a few minutes. All the shades of *golden* yellow may be obtained by using different proportions of alum along with the tin.

For a full bright yellow, delicately inclining to green, to one hundred parts of cloth use eight parts of bark, six of the murio-sulphate of tin, six of alum, and four of tartar. The green shade is more lively, if the proportion of alum and tartar be increased. A small proportion of cochineal will raise the colour to a fine orange, and even aurora.

Weld readily imparts its colour to water; it is used in the proportion of from three to six pounds for every pound of cloth: the wool is prepared by a bath containing four ounces of alum and one of tartar for every pound of cloth. A greater proportion of tartar is often employed; its effect is to render the colour more lively, but paler. Common salt deepens the colour.

Both weld and quercitron-bark are boiled in thin linen bags.

Fustic affords a more permanent yellow than weld or quercitron, but it is not so beautiful. Alum is its mordant; its colour inclines more to orange than that of weld.

To dye Wool Black.

Wool is dyed black with red oxide of iron and galls, which afford a colour not liable to fade. Logwood is employed to give lustre and fulness to the colour; but when the cloth is to be rendered as perfect a black as possible, it is first dyed blue and washed: to coarse goods, for which the blue would be too expensive, a brown is first given by walnut peels, or the root of the walnut tree.

After the cloth has been dyed blue, or brown, according to its quality, it is boiled for two hours in a decoction of nutgalls, and afterwards kept for two hours more in a bath composed of logwood and sulphate of iron, maintained during the whole time at a scalding heat, but not boiling. During the operation, the cloth must be frequently exposed to the air, because the green oxide of iron, of which the sulphate is composed, must be converted into red oxide by absorbing oxygen, before the cloth can acquire its proper colour. The common proportions are, five parts of galls, five of sulphate of iron, and thirty of

logwood, for every one hundred parts of cloth. The addition of a little acetate of copper to the sulphate of iron is considered an improvement.

To dye Wool Brown, or Fawn Colour.

Walnut-peels are generally used for dyeing a brown or fawn colour. They are the green covering of the walnut, but they soon become dark by exposure to the air. They are usually put into large casks, in which they are kept covered with water for about a year before they are used. They readily impart their colour to hot water, and nothing more is necessary than to steep the wool in the decoction of them till it has acquired the colour desired. The colouring matter is supposed to be combined with tan, for which reason no mordant is absolutely necessary, but alum, or the oxide of tin, brightens the colour. The root of the walnut-tree contains the same kind of colouring matter as the peels, but not in such abundance. The cloth should be moistened with warm water, before it is put into the vat.

Sumach, when used alone, also affords a fawn colour, inclining to green. Red saunders gives a fawn colour inclining to red; it is seldom used alone, as it affords little colour; but on account of its durability, it is used to mix with sumach, walnut-peels, galls, and alder bark, to vary their shades, and they extract more of its colour than it would otherwise yield.

Of Dyeing Silk.

The fibres of silk are naturally covered with a kind of gum or varnish, and almost the whole of the silk known in Europe has a yellowish tinge, which it is necessary to remove as well as the varnish, for most of the purposes to which it is applied. It is usually scoured with soap. The scouring is not carried so far, or in other words, less soap is used when the silk is to be dyed than when it is intended to remain white. For common colours, every 100 pounds of silk is boiled three or four hours in a solution of twenty pounds of soap, and the water is replenished as it evaporates, in order to keep the silk completely covered. The quantity of soap is increased for blue, and still more for scarlet and other bright colours, because these require a very white ground.

In purifying the silks which are to remain white, a tinge is given by the addition of a small quantity of different colouring matters; anotta is used for the China white, and a little blue for azure white.

When silk has been freed from its varnish and yellow colour, it may be whitened still further by the fumes of sulphur applied to it in a stove. But although the sulphurous acid gas thus applied, readily whitens and beautifies silk, and thereby forms a fine ground for lively colours, yet some sulphur is deposited, which must be removed by soaking and agitation for a considerable time in water, otherwise it would have the effect of tarnishing the colours given in dyeing.

The natural and much-admired lustre of silk is seen through all the colours it receives; but as acids, alkalies, and other powerful agents, tend to diminish this lustre, they ought to be sparingly used in dyeing silk.

The intervention of a mordant is necessary in nearly all cases of dyeing silk; alum is most commonly employed. After the silk is perfectly well wrung out of the solution of soap, and rinsed, it is immersed in the alum-bath for eight or nine hours, after which it is wrung and rinsed in a stream of water. For one hundred and fifty pounds of silk, the alum-bath may be composed of forty or fifty pounds of Roman alum dissolved in warm water, and afterwards added to forty or fifty gallons of water. The alum-liquor is used cold, or it would impair the lustre of the silk.

To dye Silk Blue.

Silk may be dyed blue by the indigo-vat before described; but a rather larger proportion of indigo may be used. As the silk is apt to take the colour unevenly, it should be dipped into the bath in small portions at a time, and after each portion has been turned once or twice in the bath, it should be exposed to the air, to convert its green into blue. Silks dyed blue should be speedily dried.

Indigo will not give the silk a deep blue, unless the cloth has been prepared by giving it a ground colour, before it is dipped into it. For the Turkey blue, which is the deepest, a very strong archil-bath is first used; and for the French royal blue, a weaker bath of the same kind is given. Cochineal may be used as a ground for a still more permanent blue. Verdigris and logwood are also used to impart a preparatory colour, but the blue produced with them is not permanent. If a light ground of verdigris and logwood be employed, afterwards the archil-bath, and lastly the blue, the colour is more fixed.

When raw silk is to be dyed blue, the whitest kind should be chosen; and as it takes the colour more readily than scoured silk, the latter, when it can be done, should be dyed first, if both are to be dipped in the same vat.

English blue is produced by sulphate of indigo. The silk is first dyed a light blue, and then dipped in hot water, washed in a stream, and afterwards left till the proper shade is obtained, in a bath made with the sulphate of indigo, to which a little tin has been added. The silk put into this bath, should only have been a short time in the solution of alum.

To dye Silk Red.

Silk may be dyed crimson by steeping it in a solution of alum, and then dyeing it in the usual way in a cochineal bath; but the common process is, to plunge the silk, after it has been alumed, into a bath formed of the following ingredients: two parts of white galls, three parts of cochineal, three-sixteenths of tartar, and three-sixteenths of nitro-muriate of tin, for every sixteen parts of silk. The ingredients are to be put in boiling water, in the order in which they have been enumerated; the bath is then to be filled up with cold water; the silk put into it, and boiled for two hours. After the bath has cooled, the silk is usually allowed to remain in it for three hours longer.

Silk cannot be dyed a full scarlet, but a colour approaching to scarlet may be given it, by first impregnating the stuff with murio-sulphate of tin, and afterwards dyeing it in a bath composed of four parts of cochineal, and four parts of quercitron-bark. To give the colour more body, both the mordant and the dye may be repeated. A colour approaching to scarlet may also be given to silk, by first dyeing it crimson, then dyeing it with carthamus, and lastly yellow without heat.

The poppy, cherry, rose, and flesh colours, are given to silk by means of carthamus, of which the alkaline solution, with the addition of lemon juice, is employed.

Kermes is not used for silk, and madder and Brazil-wood but seldom.

To dye Silk Yellow.

Weld and quercitron-bark are both suitable for dyeing silk yellow, and the preference in point of colour and durability, though often given to the former article, is not easily established; but quercitron is the cheapest. According to the shade required, from one to two parts of bark to twelve of silk, should be employed. The bark, tied up in a thin bag, should be put into the vat while the water is cold, and when it has acquired the heat of 100°, the silk, previously alumed, should be put in, and kept there, until it has acquired the colour desired. When a deep shade is required, a little chalk or pearl-ash should be

used towards the end of the operation. For a lively yellow, a little murio-sulphate of tin may be added; but this mordant, it must be recollected, injures the gloss of the silk.

Silk is dyed fine orange, jonquille, and aurora colours, by annatto, into the alkaline solution of which it is dipped. For the orange, the alkali is saturated with lemon juice. The colours thus obtained are beautiful, but fleeting.

To dye Silk Black.

Silk is dyed black nearly in the same manner as wool; but a greater quantity of gall-nuts are used for the gall-liquor, and the silk is allowed to remain in the warm gall-liquor for at least twelve hours, after which it is taken out and washed in running water. After the galling, the silk is put into a solution of sulphate of iron, to which gum and iron filings are usually added. When the gum is dissolved, and the bath about a boiling heat, the silk is put in by small parcels; in the course of the operation, it is occasionally taken out and wrung, and exposed to the air to deepen the colour. More of the gum and sulphate of iron is then added, if the shade be not dark enough, and the silk is again dipped and wrung out. When the dyeing is completed, the silk is well rinsed in cold water, afterwards it is kept for a quarter of an hour in a solution of soap, to take off the harshness it always receives from the black dye.

When raw silk is dyed black, that of a yellow colour is preferred; the galling liquor and the bath must both be cold, to prevent the solution of its gummy covering. If the galling liquor be weak, it will require to lie in it for some days. Black, and all other colours, are imparted to raw silk with more facility than to scoured silk, but they are less durable upon the former.

To dye Silk Brown.

Walnut-peels, managed as for wool, form a cheap and durable brown for silk, though rather dull.

Of Dyeing Cotton and Linen.

Animal substances are more disposed than those of vegetables to enter into new combinations; hence the animal substances, wool and silk, have a stronger affinity for colouring matters, and therefore are more easily dyed, and retain their colours better, than the vegetable productions, cotton and

linen. Wool is the most easily dyed, as it is favoured not only by its chemical composition, but by the peculiar organization of its surface, which facilitates the retention of the colouring particles: silk is not equal in this respect to wool; for its affinities, though similar, are weaker, and its organization is different; that it holds a middle rank between animal and vegetable substances, may be inferred from its yielding oxalic acid, when treated with nitric acid, and it may therefore be considered as drawn by the worm from a secretion not perfectly animalized. Cotton ranks next to silk in the facility with which it may be dyed, and linen and hemp the last.

The structure of the fibres of cotton is not accurately known; that they are not smooth, is evinced by their aggravating wounds, like wool and hair, if applied instead of lint; to these asperities are attributed the superiority of cotton over linen in receiving and retaining colours; for they appear to balance in part the want of the stronger affinities of animal substances. Cotton is in general nearly white; the only kind much coloured is of a brownish yellow, which is manufactured in its natural state, and sold under the name of *nankeen*, the beauty and durability of which exceeds every attempt to produce a similar colour by art.

Raw cotton, like raw silk, dyes more easily than that which has been bleached. The process used for bleaching cotton is the same as that for bleaching linen. The oxymuriatic acid prepares it well for receiving fine and permanent colours. Cotton is not so liable as wool and silk, to be injured by acids and alkaline solutions; these agents may therefore be used to it with more freedom, where they are likely to assist the colour. In scouring the raw cotton, it is usual to boil it for two hours or more in sour water or an alkaline ley, after which it is wrung out, rinsed, and dried. Manufactured goods are soaked in water containing one-fiftieth of sulphuric acid. The cotton, after it is dried, must next be alumed; a solution of four ounces of alum will be required for every pound of stuff; the cotton must be moved about in the solution to impregnate it thoroughly, and it may afterwards be left in it for twenty-four hours. It is then rinsed, and allowed to remain for one or two hours in running water.

After cotton has been alumed, it is frequently necessary to gall it; the galling must be conducted in the same manner as the aluming, excepting that the cotton need not remain above two-thirds of the time in the gall-liquor, unless intended for black. The operation is performed in the cold, when the cloth has already received a colour.

But of all the preparations which cotton undergoes for dyeing, that called *animalizing* is the most indispensable to lasting and beautiful colours. This consists in impregnating the cotton with a solution of animal matter, of which an idea may be derived from the process we shall give for dyeing Turkey red.

Flax or linen, and hemp, have, with respect to dyeing, similar properties to cotton, and undergo precisely the same operations of scouring, aluming, and galling.

To dye Cotton and Linen Blue.

Put one part of indigo, one part of green sulphate of iron, and two parts of quicklime, into a sufficient quantity of water, and let the mixture be well stirred. The solution is at first green, but it gradually assumes a yellow colour, and its surface is covered with a shining copper-coloured pellicle. The cloth is allowed to remain in the solution for five or six minutes. When taken out, it is yellowish, but it soon becomes green, and then blue, by absorbing oxygen. Haussman observes, that the cloth acquires a much deeper colour by plunging it, the instant it is taken out of the dyeing vat, into water acidulated with sulphuric acid. It is common to use a succession of baths, of different strengths, using the weakest the first; by this means the cloth receives a more uniform colour.

To dye Cotton and Linen Red.

P. J. Papillon established a dyehouse at Glasgow, for giving to cotton-yarn that beautiful colour known by the name of Turkey or Adrianople red. In the year 1790, the Commissioners and Trustees for Manufactures in Scotland, paid a premium to him for communicating to Dr. Black a description of his process, on condition that it should not be used or divulged for a certain term of years. At the expiration of the term it was published, and, as communicated by Dr. Black, it is as follows:

Step I.—For one hundred pounds of cotton, take 100 pounds of Alicant barilla, 20 pounds of pearl-ashes, and 100 pounds of quicklime. The barilla is mixed with soft water in a deep tub, which has a small hole near the bottom of it, stopped at first with a peg. This hole was covered in the inside with a cloth, supported by two bricks, that the ashes may be prevented from running out at it, or stopping it up while the ley filters through it. Under this tub is another to receive the ley, and pure water is repeatedly passed through the first tub to form leys of different strength, which are kept separate at first until their strength is examined. The strongest required for

use should bear an egg, and is called the ley of six degrees of the French hydrometer or *perseliqueur*. The weaker are afterwards brought to this strength by passing them through fresh barilla; but a certain quantity of the weak, which is of two degrees of the above hydrometer, is reserved for dissolving the oil, the gum, and the salt, which are used in subsequent parts of the process. This ley of two degrees is called the weak barilla liquor; the other is called the strong.

Dissolve the pearl-ashes in ten pails, of four gallons each, of soft water, and the lime in fourteen pails.

Let all the liquors stand till they become quite clear, and then mix ten pails of each. Boil the cotton in the mixture five hours, then wash it in running water, and dry it.

Step II.—*Bainbie, or Gray Steep.*—Take a sufficient quantity (ten pails) of the strong barilla water in a tub, and dissolve or dilute in it two pails full of sheep's dung, then pour into it two quart bottles of sulphuric acid, with one pound of gum arabic, and one pound of sal-ammoniac, both previously dissolved in a sufficient quantity of weak barilla water; and lastly, 25 pounds of olive oil, which has been previously dissolved or well mixed with two pails of the weak barilla water.

The materials of this steep being well mixed, tramp or tread down the cotton into it until it is well soaked; let it steep 24 hours, then wring it hard and dry it.

Steep it again 24 hours, and again wring and dry it.

Steep it a third time 24 hours, after which wring and dry it, and lastly, wash it well and dry it.

Step III.—*The White Steep.*—This part of the process is precisely the same with the last, except that the sheep's dung is omitted in the composition of the steep.

Step IV.—*Gall Steep.*—Boil 25 pounds of galls, bruised in ten pails of river water, until four or five are boiled away; strain the liquor into a tub, and pour cold water on the galls in the strainer, to wash out of them all their tincture.

As soon as the liquor is become milk-warm, dip the cotton hank by hank, handling it carefully all the time, and let it steep 24 hours. Then wring it carefully and equally, and dry it well without washing.

Step V.—*First Alum Steep.*—Dissolve 25 pounds of Roman alum in 14 pails of warm water, without making it boil; skim the liquor well, and add two pails of strong barilla water, and then let it cool until it be lukewarm.

Dip the cotton, and handle it hank by hank, and let it steep 24 hours; wring it equally, and dry it well without washing.

Step VI.—*Second Alum Steep.*—This is performed in every particular like the last, excepting that, after the cotton is dry, it is steeped for six hours in the river, and then washed and dried again.

Step VII.—*Dyeing Steep.*—The cotton is dyed by about ten pounds at once; for which take about two gallons and a half of ox-blood, and mix it in the copper with 28 pales of milk-warm water, and stir it well; then add 25 pounds of madder, and stir all well together. Then, having before-hand put the ten pounds of cotton on sticks, dip it into the liquor, and move and turn it constantly one hour, during which gradually increase the heat until the liquor begins to boil at the end of the hour. Then sink the cotton, and boil it gently one hour longer, and lastly wash it and dry it. Take out so much of the boiling liquor that what remains may produce a milk-warm heat with the fresh water with which the copper is again filled up, and then proceed to make up a dyeing liquor as above, for the next ten pounds of cotton.

Step VIII.—*The fixing Steep.*—Mix equal parts of the gray-steep liquor, and of the white-steep liquor, taking five or six pails of each. Tread down the cotton into this mixture, and let it steep six hours; then wring it moderately and equally, and dry it without washing.

Step IX.—*Brightening Steep.*—Ten pounds of white soap must be dissolved most carefully and completely in 16 or 18 pails of warm water; if any little bits of the soap remain undissolved, they will make spots in the cotton. Add four pails of strong barilla water, and stir it well. Sink the cotton in this liquor, keeping it down with cross sticks, and cover it up; boil it gently for two hours, then wash it and dry it, and it is finished.

Vessels.—The number of vessels necessary for this business is greater in proportion to the extent of the manufactory; but in the smallest work it is necessary to have four coppers of a round form.

1st, The largest, for boiling and for finishing, is 28 inches deep, by 38 or 39 wide in the mouth, and 18 inches wider in the widest part.

2nd, The second, for dyeing, is 28 inches deep, by 32 or 34 in the mouth.

3rd, The third, for the alum steep, is like the second.

4th, The fourth, for boiling the galls, is 20 inches deep by 28 wide.

A number of tubs, or larger wooden vessels, are necessary, which must all be of fir, and hooped with wood or with copper. Iron must not be employed in their construction,

not even a nail of that metal; but where nails are necessary they must be of copper.

By the pail is always understood a wooden vessel, which holds four English gallons, and is hooped with copper.

In some parts of the above process, the strength of the barilla liquor or liquors is determined by telling to what degree a *perseliqueur* or hydrometer sinks in them. The *perseliqueur* was of French construction. It is similar to the glass hydrometer used by the spirit-dealers in this country; and any artist who makes these instruments will find no difficulty in constructing one, with a scale similar to that employed by Papillon, when he is informed of the following circumstances:

1st, The instrument, when plunged in good soft water, at the temperature of 60 degrees, sinks to the 0, or beginning of the scale, which stands near the top of the stem.

2nd, When it is immersed in a saturated solution of common salt, at the same temperature of 60°, it sinks to the 26° of the scale only; and this falls at some distance from the top of the ball. This saturated solution is made by boiling, in pure water, refined sea or common salt, till no more is dissolved, and by filtering the liquor when cold, through blotting paper.

It should also be observed, that whenever directions are given to dry yarn, to prepare it for a succeeding operation, that this drying should be performed with particular care, and more perfectly than our driest weather is in general able to effect. It is done therefore in a room heated by a stove.

For giving a common madder red to cotton or linen, the cloth is galled, dried, then impregnated with acetate of alumine diluted with hot water; dried a second time, maddered, washed, and dried again.

The scarlet and crimson communicated to cotton by the use of cochineal is not permanent.

To dye Cotton and Linen Yellow.

Cotton and linen may be dyed yellow in a weld bath, after having been previously alumed for twenty-four hours, and dried without washing. A pound and a quarter of weld may be used for every pound of cloth, which, when taken out of the weld bath, is put into a solution of sulphate of copper equal to one-fourth of the weight of the cloth. Dr. Bancroft proposes the following as a cheaper and better method of dyeing cotton yellow.

Form a mordant by dissolving one pound of acetate of lead, and three pounds of alum, in a sufficient quantity of warm

water. In this liquor, heated to 100 degrees, the cotton is to be steeped two hours, after being first properly rinsed. It is then taken out, and moderately pressed over a vessel, to prevent waste of the liquor. It is then dried in a stove heat, and after being again soaked in the aluminous solution, is wrung out a second time and dried; it is then barely wetted with lime-water, and afterwards dried; and if a full and bright colour is wanted, it may be necessary to soak the stuff again in the diluted aluminous mordant, and after drying, to wet it a second time with lime-water; after it has been soaked for the last time, it should be well rinsed in clean water, to separate the uncombined portion of the mordant, which might injure the application of the colouring matter. By the use of lime-water, a greater proportion of alumine combines with the stuff, as well as a certain portion of lime. In the preparation of the dyeing bath, from 12 to 18 pounds of quercitron-bark are inclosed in a bag, for every 100 pounds of the stuff, varying the proportion according to the shade required. The bark is put into the water while cold, and immediately after the stuff is immersed, and agitated or turned in it, for an hour or an hour and a half, during which time the water should be gradually heated, and the temperature raised to 120 degrees. At the end of this time the heat is increased, and the dyeing liquor brought to a boiling temperature; but at this temperature the stuff must only remain in it for a few minutes, because otherwise the yellow assumes a brownish hue. The stuff having thus acquired a sufficient colour, is taken out, rinsed, and dried.

To imitate the colour of the cotton called nankeen, a cold solution of sulphate of iron is used; it is afterwards put into a ley of potass, and then allowed to remain five hours in an alum bath: but the colour obtained has neither durability nor beauty; and is stained by an accidental drop of the weakest astringent, such as tea.

To dye Cotton and Linen Black.

A full and durable black is much wanted for linen and cotton: the blacks at present in use are given by iron, which has so weak an affinity to these materials, that the colour will not bear the action of soap. In the first place, a preparation called iron-liquor, is made by putting pieces of old iron into a vessel containing vinegar or alegar; the liquor is allowed to remain six weeks or two months before it is used, in order to be fully saturated with iron. Astringents are frequently added, particularly the decoction of alder-bark, which of itself has the property of dissolving oxide of iron. The longer this liquor is

exposed to the air the better; the cask containing it is called the *black cask*. At Manchester, they prepare the cloth by a bath of galls or sumach, then dye it in the iron-liquor, and afterwards dip it into a decoction of logwood and a little verdigris. This process is repeated till a deep black is obtained, the stuff being washed and dried after each operation. At Rouen, they generally dye the stuff blue in the first instance.

To dye Cotton and Linen Brown.

A brown or root colour may be communicated to cotton and linen by walnut-peels, in the same manner as to wool and silk; sometimes a browning is given by soot, after the welding, and by a madder-bath to which galls and fustic have been added.

Of Compound Colours for the different Sorts of Stuff.

In dyeing, those colours are called simple, which are generally produced by a single operation; hence blue, red, yellow, black, and brown, (or fawn or root colour,) are called simple colours, although all other colours may be made by combinations of the three first. Of these five colours, as applied to different kinds of stuff, we have treated in succession; it remains to devote a small space to their most important combinations.

Mixtures of Blue and Yellow.

To this class belong all the various shades of green. To dye wool green, the two colours of which green is composed, are imparted to it separately: the blue is generally given first, because the yellow dye of the cloth would injure the blue bath. The green will be dark in proportion as the blue is more intense. The cloth is prepared as for welding, and dyed yellow, and afterwards blue, in the baths already described. When a dark shade is required, the strength of the yellow bath should be increased.

Sulphate of indigo is used for Saxon greens. Dr. Bancroft directs for this dye, that from six to eight pounds of quercitron-bark, enclosed in a bag, should be put into the bath for every hundred pounds of cloth, with only a small proportion of water, just as it begins to grow warm. When the water boils, six pounds of the murio-sulphate of tin should be put in, and a few minutes after, about four pounds of alum; these having boiled five or six minutes, cold water should be added,

and the fire be diminished, so as to bring down the heat of the liquor nearly to what the hand is just able to bear. Immediately after this, as much sulphate of indigo is to be added, as will suffice to produce the shade of green required, taking care to mix it thoroughly with the bath. The cloth, previously scoured and moistened, should then be expeditiously put into the liquor, and turned very briskly through it for a quarter of an hour, that the colour may apply itself evenly in every part. By these means, very full, even, and beautiful greens may be dyed in half an hour; but during this space it is best to keep the liquor at a little below the boiling heat.

Silk, cotton, or linen, intended to receive a green, is scoured in the usual manner, and the scouring is to be carried farther the lighter the shade required; it is then strongly alumed, and, like wool, dyed yellow first with weld or quercitron; it is then, after washing, immersed in the blue vat. The shade may be deepened and varied by adding logwood, fustic, or anotta to the yellow bath. The Saxon green formed by sulphate of indigo with fustic, is not so durable as the green above described.

The different shades of olive and drake's neck green, are given to cotton, after it has received a blue ground, by galling it, dipping it in a weaker or stronger bath of iron-liquor, then in the weld-bath, and afterwards in the bath with sulphate of copper: the colour is brightened with soap.

In dyeing at two operations, it is proper not to rely entirely on the proportions of the ingredients used, but to judge by the effect of the different dyes on small specimens, before the whole is dipped.

Mixtures of Blue and Red.

Mixtures of blue and red comprehend all the shades from a deep violet to lilac and dove-colour.

For violets or purples, wool should first be dyed blue, then boiled with alum and two-fifths of tartar, and afterwards dipped in a bath composed of nearly two-thirds of the quantity of cochineal required for scarlet, with the addition of tartar. The same process is followed as for dyeing scarlet, and the bath that has been used for scarlet is employed with such additions of cochineal and tartar as the shade may require.

For lilacs, dove-colours, and other lighter shades, the cloth may be dipped in the blue-bath which has been employed for violet and purple, and is somewhat exhausted, and to which some alum and tartar must be added. For reddish shades

such as peach-blossoms, a small proportion of solution of tin is added.

Logwood, with the help of galls, yields a fine purple, but the usual methods of fixing it are not effectual. Decroizille used for it a mordant consisting of a solution of tin in a mixture of sulphuric acid, common salt, and water; to which were added red tartar, and sulphate of copper. Thus he obtained a dye which is asserted to be durable. If the wool is to be dyed in the fleece, it will require a third of its weight of this mordant, but for cloth a fifth will be sufficient. A bath is to be prepared as hot as the hand can bear, with which the mordant is to be well mixed, and the stuff is to be dipped in it and stirred; the same temperature is to be kept up for two hours, and increased a little towards the end; after which the stuff is to be taken out, aired, and well washed. A fresh bath of pure water is prepared at the same temperature, to which a sufficient quantity of the decoction of logwood is added: in this the stuff is immersed and stirred; the heat is then increased to the boiling temperature, which must be continued for fifteen minutes; the stuff is then taken out, aired, and carefully rinsed. If the decoction of one pound of logwood has been used for every three pounds of wool, and a proportionate quantity for stuffs that require less, a fine violet is produced; to which a sufficient quantity of Brazil wood imparts the shade known in France by the name of *prune de Monsieur*.

The above mordant gives a greater durability than any other to the colours of Brazil, fustic, and yellow wood, and it is said to leave the wool in a state peculiarly adapted to spinning. The dyes of logwood and Brazil are apt to be injured by the alkali of the soap used in fulling; but they may be recovered and brightened by a warm bath slightly acidulated with sulphuric acid.

To give the finest violet or purple to silk, the stuff must be passed through the cochineal-bath, and afterwards dipped in a weak blue vat, having been previously prepared as for crimson, with the omission of tartar and solution of tin. Light shades are brightened by passing them through an archil-bath. For light and reddish shades, such as that of peach-blossoms, the cochineal-bath must be proportionately weak. The false or fading violet is given to silk by archil.—Decroizille's process for dyeing wool purple with logwood, is also applicable to silk.

Cotton and linen intended for violet, receive a blue ground first, and are then dried; they are next galled, and dried again; they are then put into a decoction of logwood, to which two

drams of alum and one of dissolved acetate of copper is added for every pound of yarn; they are two or three times taken out of the bath, aired, and dipped again. The colour is moderately permanent. The use of madder instead of logwood produces the most durable violet.

Mixtures of Red and Yellow.

Mixtures of red and yellow comprehend all the colours from scarlet to that of musk and tobacco. The scarlets we have treated of along with the reds. Wool dyed red by madder, and afterwards yellow by weld, acquires a cinnamon colour, for which the most proper mordant is a mixture of tartar and alum. By using root colours, instead of weld, such as walnut-tree root, walnut-peels, or sumach, snuff, chestnut, musk, and other shades, are obtained.

Maroon and cinnamon colours, and all intermediate shades, are given to silk by different proportions of logwood, fustic, and Brazil; the bath is prepared by mixing the decoctions, which are made separately; fustic must be the prevailing colour.

To dye cotton and linen a crimson colour, begin with weld and verdigris, and then dip them into a solution of sulphate of iron. After they are dried, gall them with three ounces of galls for each pound dyed; they are afterwards dried, alumed, and maddered; and lastly, brightened by a warm solution of soap.

Olive and Gray Colours.

Olive colours are produced by the mixture of blue, red, and yellow; the blue is given first, next the yellow, and then the madder red. A kind of reddish olive is given to wool and silk by a bath of fustic, to which more or less logwood and sulphate of iron are added. Russet-olive by fustic and logwood, after welding.

D'Apligny states that a fine olive may be communicated to cotton and linen, by four parts of weld and one of potass, boiled in a sufficient quantity of water, and Brazil-wood, which has been steeped one night, boiled separately with a little verdigris; the two decoctions must be mixed in the proportions the shade requires, and the cotton and thread immersed in the bath thus formed.

Coffee, damascene, and similar shades, are produced by giving the cloth a light ground colour, and then dipping them in a bath of galls, sumach, alder bark, and sulphate of iron, till the effect desired is obtained.

For blue-grays, sulphate of indigo must be combined with the galls and copperas. Brown-gray, drab, iron-gray, pearl colour, &c. are produced with galls and copperas, upon a ground of red, or yellow, according to the shade required.

Of the Water used in Dyeing.

The kind of water used in dyeing is far from an object of indifference. That it should be free from any thing which renders it turbid, or colours it, will easily be admitted; but it may appear perfectly pure to the eye, and yet contain minerals and salts in solution, which render it totally unfit for producing delicate colours, or light shades of any colour. The operations of dyeing are generally conducted on too extensive a scale to render the distillation of water admissible; the softest water that can be obtained is, therefore, considered as the best for the purpose; such water will generally be that of rivers; but as many reasons may render it unavoidable to have no other than spring-water, which, from its greater or less impurity, is generally hard, it is usual to adopt means for the correction of the defects of water that cannot be perfectly relied upon. Waters containing calcareous impregnations, are highly prejudicial to reds, in all cases where brightness of colour is desirable; for the lime which is precipitated upon the cloth, irrecoverably tarnishes the shade. Waters, also, charged with calcareous salts, will not extract so large a quantity of colouring matter as other waters, which is another extensive source of disadvantage from the use of them. Waters holding alumine and magnesia in solution are not injurious.

Of the metallic salts, the sulphate of iron is by far the most common in waters, and its effects are very perceptible, especially when the cloth undergoes the operation of galling, as it gives a brownish tinge which modifies all other colours.

It has been found that some stagnant waters are well adapted to the use of the dyer; such waters are generally soft, and the animal matters which they contain, may cause them partially to animalize the cotton and linen.

Among the means of correcting defective water, the most common is, to use water in which the bran has been allowed to become sour, and which is called *sours*, or *sour water*. It is prepared as follows: twenty-four bushels of bran are put into a vessel which will contain about ten hogsheads. A large boiler is filled with water, and when it is just ready to boil, it is poured

into the vessel. Soon after, the acid fermentation commences, and in about twenty-four hours the water is fit for use. Water which is impregnated with earthy salts, after having been treated in this way, forms no precipitate by boiling, and acquires a considerable degree of softness.

When stuffs which have recently been dyed are washed, to clear them of all the mordant and colouring matter uncombined with them, running water is to be preferred as the most effectual, and as requiring the least manual labour.

BLEACHING.

Bleaching is the art of whitening vegetable and animal substances, particularly wool, silk, cotton, flax, and hemp, whether in their manufactured or raw state. It is, therefore, the reverse of the art of dyeing; but in the order of its use, it sometimes precedes dyeing, in order to render stuffs subsequently more capable of receiving colours; and at other times it is employed to remove the colour which dyeing has communicated.

The bleaching of wool and silk, is in fact the operation called scouring, and has been adverted to as one of the processes immediately connected with dyeing. Wool would be dissolved by a strong alkaline ley, and oxymuriatic acid would turn it yellow. Soap alone, or soap and fuller's earth, bleaches it to the utmost; and soap is the chief detersive substance used to silk. It is cotton and linen that are more particularly the objects of the processes now to come under consideration, as these substances will bear the action of menstruums which would destroy wool and silk.

Bleaching, according to the old system, is a tedious and unpleasant process, comprising a number of operations conducted in the following order, 1. Steeping and milling; 2. Bucking and boiling; 3. Alternate watering and dyeing; 4. Souring; 5. Rubbing with soap and warm water; 6. Starching and bluing.

In the first of these operations, the cloth intended to be bleached, disposed in folds, is put into warm water, where it is allowed to remain until the air-bubbles, which after 18 hours' steeping begin to arise on the surface, have disappeared; this generally happens, according to the warmth of the weather,

in from 50 to 70 hours; if allowed to remain longer, a scum which forms on the surface of the water would precipitate, and the steeping must be discontinued before this occurs. After the steeping, the cloth is taken to the mill, in which, by continual agitation with a large quantity of water, all the loose foulness is carried off.

In the bucking and boiling, alkaline leys are employed to remove that particular substance, which occasions the brown colour of the cloth. Potash is the alkali mostly employed. The ley is at first put on the cloth only blood-warm; it is then drawn off, and poured on at a greater heat, and lastly at a boiling heat. The cloth is next taken into the field and spread out, where it is watered at intervals sufficiently short to keep it constantly wet; for if allowed to dry, while strongly impregnated with alkaline salts, the texture of the cloth would be injured. After this has been attended to, about half a day, dry spots are allowed to appear before the watering is repeated. By this process, the cloth acquires a greater degree of whiteness than before it was taken out, and where the evaporation has been strongest, as on the upper side of the cloth, the colour is whitest. After the cloth has received in the field a tolerably good and uniform colour, it is fit for souring, in which operation it is steeped in sour milk, or in water soured with bran or rye-meal, and used new-milk warm; or what is still better, in water acidulated with sulphuric acid. After being sufficiently soured, which is accomplished in a few hours, the acid is entirely removed by washing in the fulling mill, and the cloth is then washed by the hand with soft soap and warm water. Coarse cloths are washed more slightly; being rubbed over with soap, they are worked between boards, called rubbing boards, which effect the purpose by the grooves they contain. The finishing operations of starching and bluing, are conducted in a similar manner to the starching and bluing of the laundry.

The various steepings, boilings, and exposures to the air, to be performed in the process of bleaching above described, consumes much time, and the manufacturer is besides very dependent on the state of the weather; but while the nature of the change produced on the linen was not understood, there appeared but little hope of materially shortening the period employed in completing them. The progress of discovery, however, in chemistry, at length threw a ray of light upon the subject, and in a short time the theory of bleaching became better known, and the practice entirely changed. Scheele having discovered the oxymuriatic acid, and noted its power in destroying vegetable colours, Berthollet, upon being made acquainted with it,

undertook, among other chemical labours, to develop its properties, and it was he who first suggested and carried into effect the design of employing it extensively in bleaching. When a coloured piece of cloth is exposed to the action of oxymuriatic acid, the colour entirely disappears in a longer or shorter period, and the acid, if the quantity of cloth upon which its action has been exerted is sufficient to exhaust it, is reduced to the state of common muriatic acid. It is evident then, that the colouring matter has lost its property of exhibiting colour by combining with oxygen; and when the cloth thus bleached has been for some time exposed to the air, it becomes yellowish, because part of the oxygen which had combined with the colouring matter flies off. An additional process therefore is necessary, and as it was found that the action of the oxymuriatic acid rendered the substance of the colouring matter soluble in alkaline lixivia, by the employment of such lixivia, a permanent white is obtained. In this new mode of bleaching, the oxymuriatic acid effects, almost immediately, a change which exposure to the atmosphere requires many weeks to accomplish, and therefore the whole process is prodigiously accelerated. Much complaint was at one time heard, with respect to the injury sustained by the cloths in the new mode of bleaching, and often with justice, as in the infancy of the discovery the want of experience was necessarily attended by the liability to error, and the want of skill, among many who were anxious to adopt it, with a view to commercial advantage, was often very considerable. But when properly conducted, it is found to be less injurious to cloth than the old mode, at the same time that it produces a much superior white.

The oxymuriatic acid for the use of the chemist, is usually obtained by distilling muriatic acid off the black oxide of manganese; but Berthollet suggested, for the use of the bleacher, the more economical method of obtaining it by the decomposition of muriate of soda, which is effected by diluted sulphuric acid, and the oxide of manganese being added to the mixture, the muriatic acid is produced, and oxygenized at the same time. The following proportions of the ingredients, are considered by T. L. Rupp as the best:

Manganese	3 parts,
Common salt	8 ..
Sulphuric acid	6 ..
Water	12 ..

The proportion of manganese must be varied according to its quality. The different ingredients should be intimately mixed, and distilled in a leaden, earthen, or glass retort. The distillation should be carried on very slowly, and heat need not be applied till the first disengagement of gas has ceased, after which a sand-bath may be employed, or if the retort be of lead, it may be placed in a vessel of boiling-water. The retort must be connected with a receiver, which is designed to collect the muriatic acid that may come over in the first instance, and from this receiver proceeds a tube, the other extremity of which enters a cask of water nearly at the bottom. By this means the gas has to rise through a considerable body of water, which is necessary, as it does not combine very readily with that fluid; its absorption is at the same time promoted by the motion of a circular frame placed in the middle of the cask, and whirled round by a handle placed at the top. The intermediate vessel for the retention of the muriatic acid may be dispensed with, by using a long-necked retort, which will condense this acid, and it may be caused to run back by giving a suitable inclination to the neck of the retort. By this means the solution of the acid can be made as strong as may be required. It requires to be stronger for coarse than for fine cloth, and for linen than for cotton. The average produce is stated by Berthollet at 100 quarts for every pound of muriate of soda that has been used.

The strength of the bleaching liquor may be tried by dropping a given measure of it into a tincture of cochineal, or a solution of indigo in sulphuric acid, of a certain strength, and by observing the discoloration produced, its strength is known.

The cloth is prepared for bleaching by keeping it for some hours in a bath of warm water, and afterwards boiling it in an alkaline ley, containing 20 parts of water, and 1 part of potash rendered caustic by one-third of lime. After this preparation, which opens its pores, removes the soluble part of the colouring matter, and thus prevents an unncessary waste of oxymuriatic acid, it must be disposed in the bleaching liquor in such a manner that every part may be equally exposed to its action. It is then alternately exposed to the action of the bleaching liquor and the alkaline ley, till it is observed to be sufficiently bleached; from four to eight immersions will be required, according to the texture and kind of the cloth, and the colours to be destroyed. Cotton is so much

more easily bleached than linen, that when the liquor has little effect on the latter, it will answer perfectly well for the former. From the great volatility of the acid, it becomes desirable to employ close vessels, and one which is extremely simple, and answers the purpose perfectly well, was contrived by Theoph. L. Rupp, and described by himself in the Memoirs of the Literary and Philosophical Society of Manchester, vol. 5, part I. It consists of an oblong deal cistern made water-tight, and the dimensions of which are adapted to the quantity and size of the cloth intended to be bleached at once. This cistern is covered by a lid, which has a rim that goes within the cistern, and fits it with tolerable accuracy, but may, if thought necessary, be further secured with pitch. Opposite each other, in a line running lengthwise in the middle of the cistern, and at a distance equal to one-fourth of the length of the cistern, are placed two upright axles of beechwood or ash, one of whose extremities turns in a wooden step or socket, at the bottom of the cistern, and the other in a socket fixed in the lid, above which they project with a square termination for a handle or a pulley to be slipped upon them. Upon each axle is tightly fastened, by sewing to itself, a piece of strong canvass, one end of which, from the top to the bottom, is left projecting a little. To these pieces of canvass, the ends of the web of calico, &c. to be bleached, may be fastened by wooden skewers, and either axle, on being turned by the handle or winch slipped on the square end at the top, will then have the calico wound upon it, and by putting the winch upon the other axle, the web will be transferred to that axle. The axles are taken out of the cistern to fasten the cloth upon them; when they are replaced, the cistern is filled with the bleaching liquor; and as by turning the winch, every part of the web is stretched in succession between the two axles, the whole will be equally bleached, which is an advantage that cannot be obtained by simple immersion. While the cloth is winding upon one of the axles, the ready motion of the other might cause it to become slack, and wind unequally; to prevent this, the axle from which it is drawn, has a small pulley slipped upon its square extremity, and a cord with a moderate weight attached to it, causes sufficient friction to make the winding regular. When the bleaching liquor is exhausted, it is let off by a spigot and faucet even with the bottom of the cistern. On each axle near the bottom of the cistern, is a plain thin cylinder of wood, the diameter of which is at least equal to the diameter of the cloth, when entirely rolled upon either axle; its use is to present a shoulder upon which the cloth may rest, and be prevented from slipping down.

Experience must be the workman's guide, in determining how long the cloth must be worked, and teach him to know the effect which a given quantity of bleaching liquor will produce on a certain number of pieces; but this knowledge, with the use of the test liquor, is acquired without difficulty.

This apparatus may easily be adapted to the bleaching of yarn; for example, if the cylinder we have described as being situated near the bottom of each axle, to prevent the cloth from slipping down, be removed to a situation just under the lid, and be perforated with holes in all directions, and tapes or strings, to support the skeins, be passed through these holes, the skeins hanging down towards the bottom of the cistern, may be revolved as if a web was on the axles, and as the motion communicated to each skein will be equal, no entanglement will occur. Several axles, fitted up in this manner, might be connected by pulleys and bands, and turned by a single winch.

To fill the cistern, a short pipe is fastened in the centre, or any other convenient part of the lid; and a pipe from the cask in which the bleaching liquor is made, passes through this pipe to the bottom of the cistern; and by adapting stopcocks to the tubes, the transfer may be made without allowing any gas to escape.

The apparatus invented by Rupp, and which we have described above, was designed to fulfil several important conditions, all of which it secures. It was designed to be simple and economical in its construction; it was required to confine completely the vapours of the oxymuriatic acid, not only to prevent the loss of allowing it to escape, but to prevent the injurious effects which the breathing of these vapours would inevitably have on the health of the workmen. It must also be observed, that as potash when mixed with the bleaching liquor had been found to prevent the escape of noxious vapours, that alkali had been employed as an essential ingredient in the modes of bleaching previously used. But as the quantity of alkali employed, and which was entirely lost, was equal to about one-fourth of the weight of the salt, it made an addition of 40 per cent. to the expense, and instead of increasing the bleaching power of the liquor, by neutralizing a part of the acid, it actually diminished this power; the advantage therefore gained by a mode of using the pure liquor appears of the first importance.

But experience evinced that something was yet required; the oxymuriatic acid alone had the effect of injuring in some degree the fibres of the cloth, and an ingredient was therefore required which should be cheaper than potash, and less in-

jurious to the power of the liquor: the three earths, lime, barytes, and magnesia, were all found to be capable of being used as substitutes, and lime soon obtained a preference on account of its being the cheapest. The first difficulty that presented itself in the use of this earth, arose out of the slight degree in which it is soluble in water: but it was found that all that was wanting could be accomplished by the mechanical suspension of the lime in water, by means of agitation, as when the oxymuriatic gas entered a close vessel where this was done, the oxymuriate of lime, which is soluble in water, was completely formed, and the clear part of the water which contained it in solution, being drawn off from the undissolved or unsaturated part of the lime, was ready for use as a bleaching liquor. Subsequently, a further improvement was made, which consists in combining the oxymuriatic acid with dry lime, and dissolving a suitable proportion of this compound to form a bleaching liquor. For this invention a patent was taken out, but the exclusive right was contested in the court of King's bench, and decided against the patentee. It is therefore open to the public, and the use of the oxymuriate of lime, thus obtained, has long been in general use. It is prepared by introducing the oxymuriatic acid, through leaden tubes, into slaked lime made from chalk. The advantages of using this salt are, that as it is easily preserved or conveyed to a distance, it can be purchased by the bleacher ready prepared, and by the solution of more or less of it, he can at all times immediately obtain his liquor of the strength he requires. The strength of the liquor may be known by the hydrometer, or by trying its effect on diluted sulphate of indigo, in the same manner as the solution of the pure oxymuriatic acid is proved; and the apparatus for exposing the cloth to its action may be the same. Objections have been made to the use of the oxymuriate of lime, on the ground of its injuring the cotton for the reception of some colours, and the oxymuriate of magnesia has been recommended as preferable: but as the latter would be six times the price of the former, the difference of expense amounts to its prohibition, unless greater advantages could be derived from the use of it than have yet appeared.

When the cloth has been completely bleached, it is rubbed hard with soft soap and warm water, and washed; it is afterwards steeped in warm water containing from one-sixteenth to one-hundredth part of sulphuric acid. By this means its whiteness is further heightened, the odour of the oxymuriatic acid which it retains is diminished, and any small quantity of iron or calcareous earth contained in the cloth is carried off.

In the last stage of the process, the cloth is exposed for a few days to the open air in the field, and frequently watered, to remove every trace of the acids which have been employed.

The colours of dyed silk or wool may be removed by the bleaching liquor, and the yellowness which it communicates to them may afterwards be removed by exposing them to the fumes of sulphur; but the practice is too hazardous for commercial use.

The use of the alkaline ley, in bleaching, is to carry off the colouring matter which the action of the oxymuriatic acid has rendered soluble, and hence the necessity for the alternate use of the two agents; but as it appeared probable that a cheaper ley, in which colouring matter was soluble, might be found than that of potash, which is usually employed, and proves very expensive; Dr. Higgins, after various conjectures and experiments on the part of himself and others, found the sulphuret of lime well adapted to the purpose. Sulphur and lime are both cheap articles; they are easily combined, and they do not injure the linen. The sulphuret of lime may be prepared in the following manner for the purpose of bleaching: sulphur, or brimstone, in fine powder, four pounds; lime, well slaked and sifted, twenty pounds; water, sixteen gallons; these are to be well mixed, and boiled for about half an hour in an iron vessel, stirring them briskly from time to time. When the agitation of boiling is over, the solution of the sulphuret of lime clears, and may be drawn off free from the insoluble matter, the quantity of which is considerable. The liquor in this state has nearly the colour of small beer, but is not quite so transparent. Sixteen gallons of fresh water are afterwards to be poured upon the insoluble dregs in the boiler, in order to separate the whole of the sulphuret from them. The water last added, is boiled, and the dregs well agitated in it, and when it has become clear, it is drawn off and added to the first liquor: thirty-three gallons more of water are then added, and the liquor is afterwards reduced to the proper state for use. When the cloth has been perfectly cleansed from the weaver's dressing, it is steeped in this liquor from twelve to eighteen hours, it is then taken out, and well washed. When dry, it is to be steeped in the solution of oxymuriate of lime eight to twelve hours, and then washed and dried. These processes are repeated till the cloth has been six times in each liquor, and it is then usually found to be completely bleached. The saving by the use of the sulphuret of lime is considerable.

The oxymuriatic acid has been extensively employed by paper manufacturers. It appears, at first view, to be well adapted to

this branch of trade, as it may be supposed that whether the rags, or the pulp to which they are reduced, is bleached, the large quantity of water employed would effectually remove every trace of the acid; but the fact is otherwise; large quantities of paper, apparently made according to the best process for bleaching, have been rendered unfit for use; and in all bleached paper, the odour of the oxymuriatic acid is more or less perceptible to the smell, when a parcel of it is fresh opened. Different manufacturers are more or less successful in their use of bleaching, but in those cases where the process is so well conducted that the use of the acid can scarcely be suspected, the care bestowed in washing the pulp causes an additional expense almost equal to that of using a more valuable rag without bleaching. The faults commonly attributed to bleached paper, and which in some degree obviously exist, are, that it is not so proper for writing upon, because the size is injured; that in course of time it weakens the colour of writing ink, and its own whiteness diminishes; that it is apt to break in the folds, and from its little coherence, is easily worn away by friction. It is said even to impair the colour of printing ink, but this has not been fully ascertained. If those who are not very well acquainted with the subject, wish to ascertain whether a parcel of paper is bleached or not, they may hold a piece of it to the fire, till it is thoroughly dried, but not browned, then, while it is yet hot, they may suddenly crumple it up in their hands. If the paper retain any injurious proportion of acid, it will by this treatment fall in pieces; but if it break in none of the creases, it may be deemed fit for any purpose.

The oxymuriatic acid has been applied to the bleaching of printed books, and impressions of engravings; but if it have the injurious effects upon paper alluded to above, notwithstanding the superior chance of having the acid extracted in the manufacture, it must be obvious that it can only be applied to those which are of little or no value until restored by its use. The paper of an engraving, however soiled by smoke, ink, &c. may speedily be restored to a brilliant white, by simply immersing it in the oxymuriatic acid, allowing it to remain a longer or shorter time, according to the strength of the acid solution, or the degree in which it is stained. When a volume is intended to be bleached, the binding must be destroyed to separate it into leaves. The leaves are then placed flat in a leaden cistern, and separated from each other by thin slips of glass or wood: or the leaves may be suspended vertically over narrow slips of wood placed very near each other. In either case, the acid must be poured in gently by the sides of the vessel, to prevent disarranging the leaves, and when the full effect has been pro-

duced on the paper, it should be drawn off at the bottom, and its place supplied by pure water, which should be changed several times, or until the smell and taste of the acid appears to be wholly removed from the paper. Chaptal observes, that when he had to bleach prints so torn that they exhibited only scraps pasted upon other paper, he was afraid of losing these scraps in the liquid, because the paste became dissolved. In such cases, he enclosed the prints in a cylindrical glass vessel, which he inverted on the water in which he had put the mixture proper for extricating the oxymuriatic acid gas. This vapour, by filling the whole inside of the jar, acted upon the print; extracted the grease as well as ink-spots, and the fragments remained pasted to the paper.

When for such purposes as bleaching prints, a small quantity of the oxygenated acid is required, without the trouble which would attend obtaining it by distillation, it will suffice to add the black oxide of manganese, or the red oxide of lead, to common muriatic acid diluted with water. The bottle in which the mixture is made should be strong, or its stopper not made very fast, as the elastic vapour which is extricated might otherwise cause an explosion. At the end of two or three hours, the acid will have become colourless, and may be used after a little further dilution. It has an acid taste, because not perfectly saturated with oxygen.

To bleach old printed paper, for the purpose of being worked up again, Pajot des Charmes directs the paper to be boiled for an instant in a solution of caustic soda. That from kelp may be used. Then steep it in soap-suds, and wash it; after which it may be reduced to a pulp. The soap may be omitted, if it be thought proper.

For old written paper, to be worked up again: steep it in water acidulated with sulphuric acid, and then wash it well before it is taken to the mill. If the water be heated, it will be more effectual.

To bleach printed paper, without destroying its texture: steep the leaves in a caustic solution of soda, either hot or cold, and then in a solution of soap. Arrange them alternately between cloths, as paper-makers do their sheets of paper when delivered from the form, and subject them to the press. If one operation does not render them sufficiently white, it may be repeated as often as necessary.

To bleach old written paper, without destroying its texture: steep the paper in water acidulated with sulphuric acid, either hot or cold; and then in a solution of oxymuriatic acid; after which immerse it in water, that none of the acid may remain behind. This paper, when pressed and dried, will be fit for use.

BREWING.

Brewing is the art of preparing a vinous liquor from farinaceous seeds, particularly malt, the liquor from which is known by the names of beer, ale, and porter.

Malt liquor is composed of water, and the soluble parts of malt and hops, fermented with yeast; we shall therefore treat in succession of the preparation and best state of its component parts for the intended purpose.

Of the Water most suitable for Brewing.

Pure water is soft and light, and the softest and lightest water is the fittest for brewing; if it possess these properties, it is of little consequence whether it be rain, river, spring, or pond water. Rain-water which has stood for some time, to deposit the foreign particles washed down with it from the surfaces on which it has fallen, is generally the softest, river-water is the next, pond-water is frequently not unsuitable, but spring-water is seldom so free from mineral and saline particles as to be preferred when any other can be obtained; the substances it holds in solution generally render it incapable of extracting the whole of the valuable parts of the malt. Water that makes good tea, or is well fitted for domestic washing, may be considered as possessing the general properties which render it suitable for brewing.

Of Malt.

Barley is converted into malt by a process called malting, which consists in causing the seed to germinate, and stopping its growth at a certain point, by drying it with a slow and regular heat; so that it shall be completely deprived of adventitious moisture, without being scorched. It is best prepared with coke-fuel. The better the malt is dried, the sounder will be the liquor brewed from it, and the longer it will keep. To make malt, the barley is covered with water, until it is completely saturated with that fluid, which happens generally in from forty to sixty hours. To allow the barley to remain after saturation, would occasion some loss of its most valuable parts: as soon therefore as the saturation is complete, the water is drained off, and it is taken to the malt-floor, where it

is left for about twenty-four hours in a heap about sixteen inches deep. It is next spread on a cool floor, turned two or three times a day, spread thinner at each turning, and sprinkled with water to keep it moist. The turning is to prevent its heating too much. As soon as the ascrospire, or future stem, begins to appear, it is taken to the kiln, and after being there dried in the gradual manner above alluded to, and cleansed from the small roots, it is fit for use. Barley, by malting, generally increases two or three per cent. in bulk, and loses about one-fifth of its weight; but the essential change produced by the process, is the full development of its saccharine matter.

To ascertain the quality of malt, bite a grain of it asunder, and if it tastes mellow and sweet, breaks soft, and is full of flour from one end to the other, it is good; if good, also, it will swim on water. When imperfectly malted, it is heavy and hard.

Pale malt is the most slowly dried, and is sold at a higher price than other malt; but it produces a greater quantity of wort than brown high-dried malt, and the liquor is sooner fit for drinking. High-dried malt is chiefly used to give a deeper colour to the liquor, but the same object may be better obtained by using burnt sugar. The following table by Combrune, will afford the means of determining, from the colour of malt, the temperature to which it has been exposed on the kiln, and the time in which the liquor prepared from it will be fit for drinking.

Degr. of Fahr.	Colour of the malt.	Time required to render the liquor fit for drinking.	Remarks.
119	White	2 weeks	These, when properly brewed, become spontaneously bright.
124	Cream-colour	1 month	
129	Light yellow	3 months	
134	Amber-colour..........	4 ..	
138	High Amber	5 ..	By precipitation, these become bright in a short time.
143	Pale brown	6 ..	
148	Brown	10 ..	With precipitation, these require 8 or 10 months to become bright.
152	High brown	15 ..	
157	Brown inclining to black	20 ..	With precipitation, these may be fixed, but will never become bright.
162	High brown, speckled with black	2 years	

Before malt is fit for the brewer, it must be coarsely ground or crushed; or the husk would in a great measure defend the grain from the action of the water. To bruise it in a mill between two iron cylinders is considered the best preparation it can have. After it has been ground or bruised, it is better to allow it to cool for a few weeks in a dry place, than to use it immediately as it comes from the mill.

Of Hops.

A liquor derived from malt only, would speedily run into the acetous fermentation; to check this propensity, therefore, and to improve the flavour, some aromatic bitter is combined with it, and of all herbs for these purposes, hops have been found the most wholesome, pleasant, and effectual. The newer the hops are, the better they answer for the brewer; their fragrance being diminished by keeping, whatever may be the care with which they are preserved. If they have been

slack-dried, or kept in a damp place, they are unfit for use. They yield their aromatic bitter more efficaciously when boiled in wort than in water; hence, to impregnate the extract from malt with a due proportion of hops, their strength, as well as that of the extract, should previously be ascertained. Private families, who regard only the flavour and salubrity of their malt-liquors, may use from six to eight bushels of malt to the hogshead of their strongest beer. The quantity of hops must be suited to the taste of the drinker, and to the time the liquor is intended to be kept. From two to three pounds will be sufficient for a hogshead, though some chuse to put in so much as six pounds.

Hops contain gallic acid and tannin; they operate by depriving wort of the mucilage which disposes it to acidify.

Mills recommends *small beer* to be brewed by itself; in which case two bushels and a half of malt, and a pound and a half of hops, are sufficient to make a hogshead.

Of the Vessels used in Brewing.

Cleanliness should be strictly maintained in each department of the brewhouse, every vessel must be perfectly free from the slightest taint or smell; for which purpose they should be repeatedly scoured with cold water, and afterwards rinsed with hot or boiling water; it would be a great advantage if the interior of all the wooden vessels were charred, as by this means their disposition to become tainted would be exceedingly diminished.

The utensils of a brewery are the following:

1. The *liquor-back*, which is merely a reservoir for the cold water.
2. The *copper*, in which the liquor is heated.
3. The *copper-back*.
4. The *mash-tun*, a wooden vessel in which the operation of mashing is performed.
5. The *under-back*, into which the wort is drawn off after mashing.
6. The *jack-back*, which receives the wort after it has been boiled with the hops, and has in some breweries a cast-iron floor, pierced with small holes, to admit the wort, but retain the hops.
7. The *coolers*, which are shallow tubs, to cool the wort in a short time, by presenting a large surface to the air.
8. The *gyle tuns* or *squares*, in which the liquor is first put to ferment.
9. *Casks*, in number and size proportioned to the quantity brewed at once.

To diminish the number of vessels required in brewing, and to simplify the operation, J. B. Bordley, an ingenious American, describes an invention of his, which is well adapted to family use. He calls it the *tripartite method of brewing*, because the kettle-apparatus is worked in three divisions. This vessel is represented at fig. 1, (pl. Brewing, &c.) The whole vessel is 40 inches long, 20 broad, and 24 deep; of these dimensions the division *a* occupies thirteen; *b* nine; and *c* two inches in the depth. The horizontal lines indicate where the perforated moveable bottoms are placed. In *a* is the water or wort; *b* contains the malt; and into *c* the hot water is pumped up, or poured over from *a* to *c*, by means of the small pump *d;* and thus passes through every particle of the malt; so that, by frequent agitation, the water washes out its whole substance, and extracts all its farinaceous and saccharine parts. This operation is repeated, occasionally stirring up the grains, till the liquor becomes clear, when it should be briskly boiled, and then drained off into coolers, for which purpose a cock is placed in one side close to the bottom. The inventor observes, that a Swedish mode of brewing in camp afforded him the hint for this process. He remarks that his tripartite kettle is made of copper; but the pump would be perhaps best made of wood, or pure tin, to prevent the formation of verdigris.

Of Mashing.

The mash-tun is shallow in proportion to its diameter, and is furnished with a false bottom, a few inches above the real one, pierced with small holes, and made either moveable or fixed. There are two side openings in the interval between the real and false bottom, to which pipes are fixed, one for the purpose of conveying water into the tun, and the other for drawing liquor out of it. The malt is to be strewed evenly over the false bottom of the tun, and then, by means of the side pipe, a proper quantity of hot water is introduced from the upper copper. The water rises through the malt, or, as it is called, the grist, and when the whole quantity is introduced from the upper copper, the mashing begins, the object of which is to effect a perfect mixture of the malt with the water, so that all the soluble parts may be extracted; for this purpose the grist is diffused through the water by means of iron rakes, and then the whole is beaten for a quarter of an hour with long flat wooden poles resembling oars, which are either worked by hand or machinery, according to the magnitude of the scale of operation. When the mashing is completed, the

tun is covered, to prevent the escape of heat, and the whole is suffered to stand about an hour and a half, when the insoluble parts will have separated from the liquor. The side hole is then opened, and the clear wort allowed to run off slowly at first, but more rapidly as it becomes fine, into the lower or boiling copper.

Great care must be taken that the water be not conveyed to the malt at a boiling heat, which would convert the malt into paste. In order to obtain it of a proper temperature, Combrune recommends, that when it boils, to every 22 given measures of it, ten equal measures of cold water should be added; this will reduce its temperature to about 161 degrees of Fahrenheit, which he considers the best heat for mashing; but it must be observed, that the darker the colour of the malt used, the lower must be the temperature of the water: for pale malt, the water may be 180 degrees; but for brown, it should be from 10 to 20 degrees lower.

The water of the first mashing is by much the richest in sac charine parts; but to exhaust the malt, a second and a third mashing is required, and the water, in these latter operations, may safely be used almost boiling hot, as for example at 190 degrees or upwards. When the liquor is intended to be all of one quality, the produce of each mashing may be drawn off into the same vessel; but if ale is to be made at the same time with beer, the produce of the first mashing should be kept apart for it.

The quantity of wort to be drawn from the malt, depends, it must be obvious, upon the strength of the liquor required. For small beer, 25 or 30 gallons may be taken from each bushel of malt; for good table beer, 2½ bushels of malt should be allowed to the cask of 36 gallons; and for ale, 4 bushels of malt for a like quantity. And in determining the quantity to be drawn off, three gallons and three quarters of water must be allowed for what each bushel of malt will absorb.

Of Boiling and Hopping.

When the wort intended for the same liquor has been transferred from the mash-tun to the lower copper, it must be mixed, while it is heating, with a due proportion of hops. In private families, where the difference of expense between a full proportion of hops, and the least quantity that will suffice, is insignificant, one pound of hops is added for each bushel of malt, whether for small beer or ale; in public breweries the proportion is rather less, and less for ale than for beer.

When both ale and beer are made from the same malt, the practice sometimes is to put the whole of the hops into the ale wort, and then exhaust them afterwards with the beer wort.

The wort for the purpose of purifying it, should be made to boil as quickly as possible, and towards the end of the boiling, the hops should be put in; if the hops be boiled for a long time, the extract obtained from them injures the flavour of the beer, and their best part flies off. In general, from five to ten minutes will be sufficient; they have produced their proper effect, when the liquor, on a little of it being taken out of the copper, is found to be full of small flakes like those of curdled soap. In small brewings, the boiling copper is uncovered, but in breweries on a large scale, it is fitted with a steam-tight cover, from the centre of which passes a pipe, that terminates by several branches in the upper copper. The steam, therefore, produced by the boiling, instead of being wasted, is let into the cold water, which it raises very nearly to the temperature required for mashing, besides impregnating it very sensibly with the essential oil or fragrant part of the hops.

Of Cooling the Wort.

When the liquor is sufficiently boiled, it is transferred from the boiling copper to the coolers, where it is exposed to a free current of air, and allowed to remain till it has deposited the hop seeds and coagulated flakes with which it was charged, and become sufficiently cold for fermentation. It is considered sufficiently cool, when the discharge of steam has so far decreased, that its surface reflects the image of the face like a mirror: but the surest mode is to use the thermometer: if intended for immediate drinking, it need not be cooled lower than 75 or 80 degrees; if designed to be kept a long time, it should at least be cooled to 65 or 70 degrees, and therefore can only be made in temperate weather.

The liquor in the coolers should be exposed to a draft of air, as if the atmosphere over it were not constantly changing, it would, particularly in hot weather, soon acquire a nauseous smell and taste, and spots of white mould would form on its surface. The coolers are generally made of wood, which conducts heat so slowly as to be unfavourable to a speedy reduction of the temperature of the wort. Metallic coolers would produce the effect sooner, and a patent has been taken out for the use of iron ones; but the most complete and rapid mode of cooling wort, is certainly that of passing it through a worm, like that of a still, contained in water kept constantly cool; by which means the fine flavour of the hops is saved.

Of Fermentation.

The change produced by fermentation in a saccharine fluid, such as wort, has already been adverted to, at page 502. It is here only necessary to observe, that when the wort has been properly cooled, and transferred from the coolers to the working tun, a pint of sound fresh yeast (from strong beer, if such can be obtained) is added for every 9 gallons of liquor. The fermentation commences at the side, and in the course of four or five hours, its effect is perceptible all over the surface. When the fermentation has attained its height, which is known by the head of yeast beginning to decline in the middle, the liquor is fit for barrelling. This is generally the case in eighteen or twenty hours, if it is let down into the tun hot: but if it be set for fermentation at 60 or 65 degrees, it requires forty-eight hours for the fermentation to attain its height; and this slow fermentation is more favourable to the goodness of the liquor than the other. It has been usually said, that a free exposure to air promotes fermentation, even if it is not necessary to it; but experiment does not confirm this opinion. Collier fermented wort as perfectly in a close as in an open vessel, with these advantages in favour of the close vessel, that the wort was incapable of the acetous fermentation, access of air being necessary to the formation of acid, and that it had not sustained by the fermentation above one-fifth of the loss of measure of the other; and therefore it afforded a proportionately greater quantity of spirit when distilled, though in the quality there was no perceptible difference. By a close vessel, in this experiment, is meant a vessel, with an air-tight cover, in which was inserted a tube that terminated in water, as represented by fig. 2, plate Brewing, &c.

When the heat of the atmosphere is more than 60 degrees, the cool of the night must be chosen for setting the wort to work, and about three o'clock in the morning may be considered the coolest part of the twenty-four hours. If the temperature of the atmosphere is several degrees below 60 of Fahr. the wort may be set at a greater heat than that of the air; for as the tendency to fermentation increases, with the heat of the weather, it is necessary to correct it, by putting the liquor to work cooler, in hot weather, than in cold. If the air is at 30 degrees, small beer should be set to work at 70 degrees; beer intended for keeping at 56°; and amber or glutinous ales at 54°. When the air is at 50 degrees, all these kinds may be set on work at 50°. In the course of fermentation, the temperature of the wort has generally risen 10 degrees, by the

time it attains its height, although the temperature of the air continues the same. Spring and autumn are considered the most favourable seasons for brewing, on account of the moderate temperature which then generally prevails.

When barrels are filled with the fermented wort, their bungholes are left open, the fermentation still goes on, and in order that the yeast may be wholly driven over, the barrel is filled up once or twice a day for a few days. In about a week it may be closed, and afterwards the liquor will become clear and fit for use.

Of fining the Liquor.

When the wort and fermentation have been perfectly well managed, the liquor in due time becomes perfectly fine and transparent in the cask; but when this does not happen spontaneously, means are used to produce it. The most usual fining is composed of sour beer brewed on purpose, without hops, from a fourth mash, and in which isinglass is dissolved. It spreads on the surface of the liquor, and sinking down, carries the impurities along with it to the bottom. This fining is not always effectual for brown beers; therefore for such, a quantity of oil of vitriol, not more than four ounces to a butt, is used.

When beer is ropy, it may be cured by putting a bunch of hyssop into the cask.

If beer has become cloudy after thunder, a gallon of it (for every 36 gallons) may be boiled for half an hour, with an ounce of new hops, and a handful of salt; this portion may be returned into the barrel, and stirred up for a few minutes with the remainder; and in about twelve hours afterwards the whole will be found to be perfectly recovered.

When beer has acquired a peculiar taste of the cask, either by long keeping, from the astringency of the oak, or for want of proper cleanliness, it is advisable to suspend in it a handful of wheat tied up in a bag; which generally removes the disagreeable taste.

Of Porter.

Ale differs from beer, in general, only in being stronger, though it is sometimes brewed with a smaller proportion of hops, and is not so much fermented as beer; but porter differs from both ale and beer, in containing several ingredients which modify the flavour of the malt and hops. Porter is often

adulterated with deleterious drugs, on which account the domestic brewing of it is desirable. Child, in his treatise, entitled "Every Man his own Brewer," has given the following recipe for preparing it in small quantity :—

	£.	s.	d.
One peck of malt	0	2	6
A quarter of a pound of liquorice root	0	0	2
Spanish juice	0	0	2
Essentia bina	0	0	2
Colour	0	0	2
Half a pound of treacle	0	0	3
A quarter of a pound of hops	0	0	6
Casicum and ginger	0	0	1
The expense of coals	0	0	6
	0	4	6

These articles, managed according to the directions for brewing, will produce six gallons of good porter, which, at 1s. 6d. per gallon, would cost nine shillings, so that one half of the expense is saved by making it at home, and independent of the economy, the liquor will be wholesome and palatable; which is not always the case with the liquor of the public breweries. By augmenting the ingredients in their relative proportions, any quantity of porter may be brewed.

It may be necessary to explain the manner of preparing the *essentia bina*, and the colour. In order to procure the former, a quarter of a pound of moist sugar should be boiled in an iron vessel till it attain the consistence of a thick black sirup, which is remarkably bitter.

The colour is produced by boiling a similar quantity of moist sugar, till it acquires a taste between sweet and bitter; it imparts the fine mellow tint so much admired in good porter.

In preparing the essence and colour, it will be necessary to employ a small portion of pure or of lime water; because they will otherwise grow hard and dry, if suffered to stand till they become cold. They are added to the first wort, with which they are boiled.

Mode of preparing Yeast.

In many situations, the yeast required for brewing cannot be obtained at all, or cannot be obtained at the time it is wanted. In such cases, the following mode of preparing yeast, invented

by W. Mason, will be useful. It is taken from the transactions of the Society for the Encouragement of Arts, &c.

Procure three vessels, of different sizes; one capable of holding two quarts, the other three or four, and the third five or six. Boil a quarter of a peck of malt, for about eight or ten minutes, in three pints of water; and when a quart is poured off from the grains, let it stand in a cool place, till not quite cold, but retaining the degree of heat which the brewers find proper for commencing fermentation. Then remove the vessel into some situation near the fire, where the thermometer stands between 70 and 80 degrees, and there let it remain till the fermentation begins, which will be in about thirty hours; add then two quarts more of a like decoction of malt, when cool; and stir it well in the larger sized vessel; then proceed as before; after which, add an equal quantity more, and mix all in the largest vessel, and it will produce yeast sufficient for a brewing of forty gallons.

DISTILLATION

Distillation is the art of separating the volatile and spirituous from the fixed and watery parts of fermented liquors.

When a fluid which has undergone the vinous fermentation, is exposed to the action of heat, the vapour which arises from it, is, when collected and condensed by the reduction of its temperature, again converted into a fluid: but the fluid thus obtained is found to have different properties to that from which it was derived, and it receives the name of *spirit*. This spirit consists of water and a peculiar fluid called *alcohol*, of which we have treated at page 504. Alcohol, in combination with more or less water, and flavoured by the aroma of the different substances from which it is obtained, forms brandy, rum, geneva, and all the various descriptions of spirit known in commerce. The art of the distiller consists in selecting the most convenient mode of heating the fermented fluid, of condensing the vapour it affords, while he prevents the intermixture with his products of whatever would injure their flavour; and to accomplish these purposes, although apparently so simple, it is found that great care and skill are required.

The distillations performed by the chemist, with the retort, the alembic, the lamp-furnace, the pneumato-chemical and Woulfe's apparatus, for obtaining gaseous and volatile pro-

ducts in general, are essentially the same as the distillations conducted for the commercial purpose of obtaining spirit; but the scale is different: the chemist has his whole apparatus so completely under his eye, that he can adjust the heat and other circumstances with great nicety: when he has vapour to condense, in using, for example, the lamp-furnace, a wet sponge placed on the beak of the retort will suffice; but the commercial distiller requires for the purpose of condensation, a long convoluted tube, passing through an immense body of water, which must be constantly renewed; the difference of scale, therefore, requires more than a mere enlargement of the apparatus, and there has in fact been found ample scope for improvements in the art.

The substances from which spirit is obtained are usually barley, wheat, oats, rye, sugar, or molasses. In countries where the grape ripens in the open air, wine is distilled for this purpose: hence the superiority of the brandies of France; the spirit afforded by good wines containing the finest aroma of all products capable of yielding alcohol. When grain is used, it is malted according to the usual process, like barley for brewing; and the fermentation is conducted in the same manner. After fermentation, the fluid intended to be distilled is called *wash*, and it is ready for the still.

A still consists of a boiler, which contains the wash; and a tube, in passing through which the vapours are condensed; the tube is convoluted, in order that it may have a great length in a moderate compass, and it is thence called the *worm*. The boiler formerly used, was a cylinder, the height of which was in general one-half greater than its diameter; but the French, who have always been foremost in the improvements which this art has received, have introduced a much superior form, see fig. 3, (plate Brewing—Distilling.) The height of the boiler has been considerably diminished, its width augmented, and instead of being cylindrical, it widens upwards gradually to within about three or four inches of the top; there the sides are curved into an arch, and become narrower; hence its form is in fact similar to that of a common tea-kettle: the mouth *c d*, is of the same diameter as the bottom *a b*. To the boiler is fitted a conical head, in the interior of which, round the lower edge, is a channel, destined to receive the liquid condensed against the sides, and which, instead of returning to the boiler, is conveyed into the worm. In the old construction, the head communicated with the worm by an inclined tube of a very small diameter; but now the tube in this situation, at its base *f g*, is as wide as the head, and diminishes in diameter as it approaches the worm, into which it opens. Another important

difference between the new boiler and the old one, consists in the shape of the bottom; the old ones were flat; this is concave, in the manner shewn by the dotted segment of a circle *a b*. By this means, the heat received is nearly equal at every point directly exposed to the fire; and as the bottom is convex within, the sediment from the wash falls round its edge, where from its resting on the brick-work, and not receiving the direct heat, it is not liable, from being burnt, to give an empyreumatic taste to the spirit. Two inches of the circumference of the bottom rest on brick-work. The boiler is filled by the aperture *o*.

In the old construction of the furnace, the heat was applied only to the bottom of the boiler; and a further loss was sustained by placing, as is still common in furnaces generally, the centre of the grate under the centre of the boiler; without reflecting that the stream of air towards the chimney always carries the heat and flame in an oblique direction towards the end of the boiler. At present the end of the grate next the chimney is not placed further back than the middle of the boiler, and the heated air is conducted round the boiler before it passes off, by which the whole mass of fluid in the boiler is heated at once, and the heat may be maintained with great regularity, while a much less quantity of fuel will suffice. The brick-work surrounding the boiler reaches as high as the circle *k k*.

The worm is generally made of tin or pewter, and is the same as that in common use, except that at the commencement *l*, where it is connected with the beak of the head of the boiler, it is wider than they were formerly made, and tapers gradually towards the discharging extremity *m*. The reason of this is evident, because vapour, only partly condensed, requires more room than when the whole is fluid. The refrigeratory, or vessel AB, is kept constantly filled with cold water; this is effected by a tube *n*, which descends and opens nearly at the bottom of it, and brings a supply of cold water from a greater elevation; while another tube, *r*, conveys the hot water with equal rapidity from the top. By this means the condensation is so complete, that the spirit discharged at *m*, exhales little or no odour. As it is often not possible to have the water from a greater elevation than the refrigerator, without raising it by mechanical means, the following plan, by Alexander Johnston, is highly entitled to attention, as in it the siphon is applied to the worm-tub as a refrigerator; and water is conveyed in any quantity to a worm-tub of the largest dimension, if perfectly air-tight; it is represented at figure 4, (pl. Brewing—Distilling.) A, is the feed pipe of cold water. B, the hot water, or

waste pipe, the end of which must be about two feet lower than the feed pipe, to make it act with full effect.

When the work is commenced, the cocks must be shut, and the tub filled through a hole at the top, and of course, both pipes; and, when full, the hole at the top is to be stopped, and the cocks opened together; the water will then commence running, and continue as long as the supply holds good, as it acts in every respect on the principle of a siphon. By this means, pumps, horse-mills, and other machinery, are rendered unnecessary for that purpose. The application of this improvement is simple, and executed at a very little expense. The saving, for the city of Dublin alone, is calculated at upwards of one hundred horses per annum.

The quantity and excellence of the spirit produced by the French, in consequence of the alterations they have made in the old method of distilling, have decisively shown the value of the new plans, which may be adopted without the disadvantage of increasing the first cost or complexity of the apparatus; but the apparatus required for the more recent improvements in distillation, are liable to both these objections, although it must be allowed that they appear to carry the art to perfection. They consist in the application of Woulfe's apparatus to this purpose; wine being put into the boiler, and into all the intermediate receivers between the boiler and the worm, the tube from the boiler plunges into the wine of the first receiver, to which it communicates sufficient heat to raise its contents in vapour; this vapour has the same effect on the wine of the next receiver, and after the continuation of the process through as many receivers as may be thought proper, the whole of the vapour finally extricated is condensed in the usual way by passing through a worm. By this truly ingenious apparatus, spirit of various degrees of concentration may be obtained at one operation, according as the product of the first, the second, or any other receiver, is taken; the consumption of fuel is extremely small; the products excellent, as well as greater in quantity than by any other means; and by using water instead of wine in the boiler, the possibility of an empyreumatic taste is prevented.

In distilling from grain, an oil is apt to come over, which injures the taste of the spirit; it is usual to keep it back by adding a little sulphuric acid to the wash.

The comparative salubrity of the spirit or geneva made in Holland is notorious, and it has been supposed that nothing like it can be produced in this country; but it appears to be entirely the result of the care they take in their processes. They use the most perfect grain, and use it only when perfectly

malted, aware that a fourth part more spirit is obtained from such grain, than from that of which the germination has been checked too soon, or suffered to continue too long. The best Hollands is prepared from wheat, which is the fittest grain for this use, and is more productive than barley; but rye yields about one-third more spirit than wheat, and is more extensively used in Holland. The fermentation is continued about three days: the first distillation is extremely slow; and and the observation of this point is essential; the second distillation, or rectification, is done with juniper berries. The most rigid cleanliness is observed; and the vessels are cleansed with lime-water, instead of soap, which would give the liquor a urinous taste. They use the rye grown on a calcareous soil, and never, if they can avoid it, that of fat clayey ground. It is Prussian rye they employ. A little malt added to rye improves the flavour, but not the quantity of the spirit.

The rectification of spirits consists in the re-distillation of them in order to make them clean, and increase their strength; and in this no difficulty occurs, if the first distillation have been well conducted. When the distillation has been performed twice in the common way, for which purpose the spirit is mixed with an equal quantity of pure water, and a little soda is put in, it is often performed for the last time with a water-bath. If the liquor has been burnt in the still, it is put into charred casks for some weeks, and is mixed with charcoal powder when distilled.

A clean spirit, that is, one perfectly free from its own essential oil, is used to digest with substances containing agreeable essential oils, such as cinnamon, aniseed, &c. and on these mixtures being distilled, the spirit having extracted their oils, comes over impregnated with them. It is in this way that the various kinds of *cordial waters* are prepared; and which, instead of the delusive name they have received, ought to be characterized in a manner indicative of their destructive effects on the human constitution when used as a beverage: the term *liquid-fire* has not unaptly been given them.

With respect to the usual mode in which distillation is conducted in the great public distilleries, the most interesting account that has been communicated to the public, is that contained in the deposition of James Forbes, of Dublin, who was for many years concerned in a large distillery. It is from the Appendix to the Fifth Report of the Commissioners of Inquiry into the Fees, &c. received in the Public Offices of Ireland; which report was printed by order of the House of Commons:

"The corn is first ground, then mashed with water, and the

worts, after being cooled, are set for fermentation, to promote which, a quantity of barm is added to them, and they become wash; the wash is then passed through the still, and makes *singlings*, and these being again passed through the still, produce *spirits;* the latter part of this running being weak, is called *feints*. When singlings are put into the still, a small quantity of soap is added, to prevent the still from running foul, a dessert spoonful of vitriol well mixed with oil, is put into a puncheon of spirits, to make them show a bead when reduced with water: this is only done with spirits intended for home consumption, and no vitriol is used in any other part of the process. In this distillery, the former practice was to use about one-fourth part of malt, and the remainder a mixture of ground oats and barley, and oatmeal; latterly the custom has been to use only as much as would prevent the kieve (mash-vat) from setting. He had found that malt alone produced a greater quantity of spirits than the mixture of malt and raw corn of the same quality with that of which the malt had been made. He generally put from 50 to 54 gallons of water to every barrel of corn of twelve stone, (14lb to the stone.) Each brewing was divided into three mashings, nearly equal: the produce of the two first was put into the fermenting backs, and the produce of the last, which was small worts, was put into the copper for the purpose of being heated, and used as water to the next day's brewing, when as much water was added as would make, with the small worts of that brewing, 54 gallons to each barrel of corn. The kieves were so tabulated that he always knew the quantity of worts which would come off at each mashing. Their strength he ascertained by Saunders' saccharometer, and at the above proportions he obtained from a mixture of the two first worts, an increase of gravity from 20 pounds to 22 pounds per barrel, of 36 gallons, above water-proof, at a temperature of about 88°. The small worts gained at the same temperature about six pounds. The grain, after the last worts were off, retained nearly the same bulk as when put into the kieve; the whole of the grain was put in at the first mashing; he never knew any grain to be added to the second mashing. The worts of the first and second mashing were run through the mash-kieve into the under-back, in which state they were usually found to correspond with the computation made in the mash-kieve and under-back, in the latter of which a correct gauge might be taken of them. He usually commenced brewing at six o'clock in the morning: the first worts were run off into the under-backs, and required from an hour to an hour and a half to be forced up into the cooler; the second worts came off at the end of two hours from the dis-

charge of the first, and required about the same time to pass into the coolers. The small worts were generally run off late at night, and being then, or early on the following morning, put into the copper to be used for the next brewing, were seldom shown on the coolers. He thinks that any decrease of the worts by evaporation whilst on the coolers, must have been very inconsiderable; and that a correct gauge of the worts might be taken in the coolers, as well as in the under-backs. The quantity of wash in the backs, was found to be nearly correspondent with that of the strong waters which had been on the kieve and in the cooler. The fermentation of the worts was produced by means of yeast, and was in general so contrived as to be apparently kept up for the full time allowed by law (six days:) he has, however, usually had his wash ready for the still in twenty-four hours from the time in which it was set. Backs are renewed in two ways; either by additions made to them from other backs in the distillery, each supplying a certain portion of wash to the back which is next before it in the order of fermentation, while the newest and least-fermented wash is replenished by worts, or when the fermentation is down, by an entire substitution of worts. He has ordinarily in the course of work, charged a 500-gallon still with wash, and run it off in twenty to twenty-three minutes: he has seen a 1000-gallon still charged and worked off in twenty-eight or thirty minutes. He understands that it is now the practice of some distillers, to heat the wash nearly to the state of boiling before the still is charged with it, by which means he believes the process to be accelerated by three or four minutes. He has seen a 1000-gallon still charged with singlings, and worked off in from forty to fifty minutes, and thinks a 500-gallon still requires nearly an equal time. Feints from pot-ale (the name given to completely fermented wash) usually are run off in from six to seven minutes; making allowance for every delay, about six charges of spirits may be run off from a still of 500 gallons content, each charge estimated at 150 gallons. The feints were always put back into the pot-ale receiver; 20 gallons of feints is the usual quantity run from a 500-gallon still charged with singlings; he thinks there is more spirit extracted from feints than from pot-ale; there was no delay between one charge of pot-ale and another, or between one of singlings and another; the still could be cleansed in less than a minute; it very rarely occurred that the ordinary accidents which happened to the still delayed the work to any considerable degree. The still is never charged with wash beyond about seven-eighths of the still, nor with singlings beyond about four-fifths, exclusive of the head. The estimated produce (accord-

ing to which the duty may be charged) is one gallon of singlings from three gallons of wash, and one gallon of spirits from three gallons of singlings, but it is very frequently somewhat more. Previous to the regulation (of Excise) which took place in June, 1806, from a still of 540 gallons, which is charged with 2075 gallons of spirits weekly, he has frequently drawn 5300 gallons in one week, and thinks 500 gallons to be a fair average. He usually made spirits about 14 per cent. above proof, by Saunders' hydrometer. Spirits exported by him from 12 to 14 per cent. above proof by Saunders' and Hyatt's hydrometer, were charged in London at from 24 to 26 gallons per cent. Before he sent them to the Custom-house, he either reduced them with water, or drew them at that strength from the still. To every six gallons of strong spirits, one gallon of water was added in the distillery, which reduced them to the strength usual for exportation. The reduced spirits are permitted to the king's warehouses, and the distiller given a credit for a decrease of stock equal to the quantity so permitted; by these means he has one gallon of private spirits to dispose of for every gallon of water mixed with the spirits exported; besides this, the distiller draws back the allowance given in lieu of the malt-duty on every gallon of water added: when he warehoused spirits with the intention of afterwards using them for home consumption, he left them at their full strength."

BREWING – DISTILLATION.

Fig. 1.

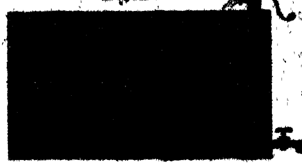


Fig. 3.

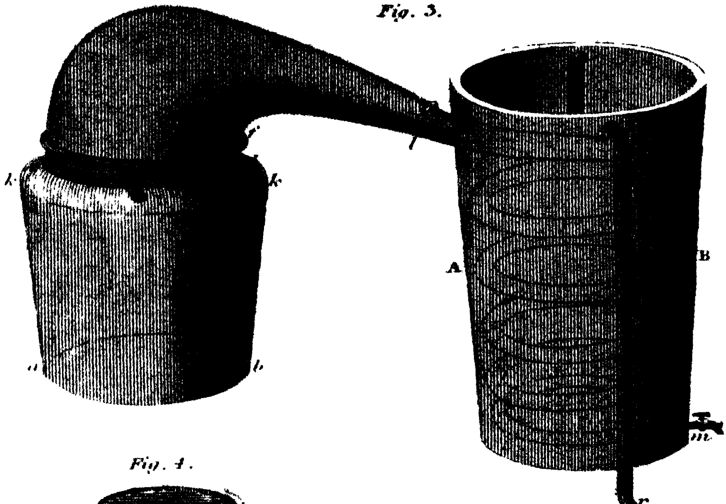


Fig. 4.

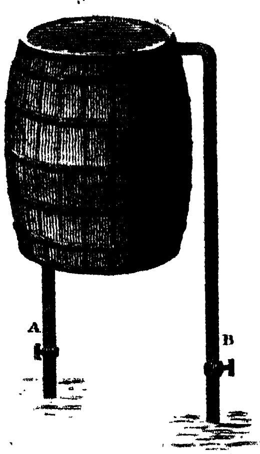
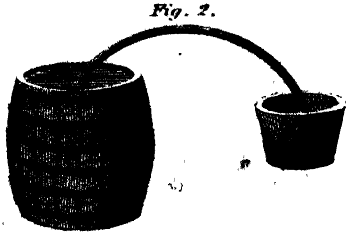


Fig. 2.



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AGRICULTURE.

Agriculture teaches the art of increasing the production of useful vegetables by cultivation.

Although in the labours of a single husbandman, persons of common observation are not apt to see any thing important, yet when a comprehensive view is taken of human affairs, it is found that such labours are indissolubly connected with the independence, the greatness, and happiness of nations. The spontaneous bounty of nature would supply but a small part of the present inhabitants of the world with food; a single family would consume the produce of a district sufficiently extensive to be rendered capable of supplying the wants of thousands; with the assistance of cultivation, a thousand millions added to the present population of the earth, which is perhaps already equal to that number, could demonstrably be supplied with abundance. Let us, for example, look at the state of Great Britain, where the value of estates is extremely high, and where, from the freedom of the government, the spirit of agricultural improvement is eminent. Sir John Sinclair estimates this country to contain.....67,000,000 of acres,

Of which, deducting, for houses, roads, rivers, lakes, and other parts incapable of cultivation,.......... 7,000,000

There remains for productive purposes ....60,000,000 of acres,

Of these 60,000,000 of acres, 5,000,000 only are employed in raising grain,

25,000,000 are in pasturage,

And no less than..........30,000,000 are either entirely waste, or but imperfectly cultivated.

60,000,000

From this data it may be fairly concluded, that if the most useful routine of crops, and modes of management, were generally applied to land already in tillage, and the proportion designated as barren, were fully subjected to improvement, a double population would not be sufficient to consume the produce of Great Britain. But a change so beneficial cannot be suddenly effected; it can only arise from the prevalence of knowledge, which is acquired but slowly; the dissipation of prejudices, which are deeply rooted; and the sacrifice, on the part of individuals, of privileges, which, though acquired by violence and falsehood, or founded upon injustice and mistaken views, having been sanctioned by time, are with difficulty abrogated. If oppressive tenures were commuted; if tithes were abolished; if the game-laws were only a dead letter on our statute-books; if the length of leases, and the probability of having them renewed on equitable conditions, gave tenants a sufficiently permanent interest in the lands they occupy,—the spirit of improvement would acquire a strength and energy, which in the present state of things it is vain to expect.

Researches on the subject of population, render it perfectly evident, that population increases with the facility of obtaining sustenance; the man, therefore, whose exertions are directed, with an enlightened zeal, to the extension of the means of rendering the acquisition of livelihood easy, is justly entitled to the appellation of a real patriot, and a friend to the human race. To increase the fertility of an estate, is virtually to extend its surface; it has the effect of territory acquired without dispossessing others. The agriculturist, therefore, has the noblest motives to stimulate him, besides the ordinary one of pecuniary remuneration; it is only where discretion fails, that the earth will not eventually afford an ample return for the labour it receives.

The first object of the farmer should undoubtedly be to obtain a general idea of the nature of the soil which he intends to cultivate, as his future views must be entirely limited by its present or probable fitness for particular purposes. To this subject we shall therefore direct our attention in the first instance.

Of Soils.

The soil or mould which forms the uppermost strata of the earth, consists principally of argillaceous, calcareous, and siliceous substances, which of themselves form no part of the nutriment of plants. Their use is almost entirely of a mechanical nature; by the support they afford, and by their conveying to the roots the nourishment they require in proper quantity. The real nutriment of plants consists of water, and the substances which this fluid holds in solution. Part of the water which plants draw up, they retain in the state of water; another part they decompose, and appropriate its constituent principles, so as to form new substances; the useless part of the water, and of the principles into which it has been separated by the organic operations of the plant, is thrown off by transpiration. The component parts of dead animal and vegetable bodies, are rendered by putrefaction soluble in water, and these component parts being the same as those of living vegetables, their use as manures is evident. As different plants acquire different principles from the soil, it can be no object of surprise that they require difference of soil to make them flourish. When, therefore, a soil is of such a nature, that the plants which grow in it receive their nourishment in a proper state and quantity, such plants will thrive; and the art of the agriculturist consists in effecting this adaptation of the plant to the soil.

According to the predominance of particular ingredients, soils are said to be clayey, chalky, sandy, gravelly, loamy, peaty, and marshy; to which may be added, the description called a vegetable soil. Of these different kinds, we shall briefly treat separately.

Of Argillaceous or Clayey Soils.

For an account of clay, in its purest state, and all the other earths and substances which we may have occasion to mention in this essay, we must suppose the reader to refer to the article Chemistry. They are never met with pure in soils, but, of course, the larger the proportion in which they subsist, the more of their peculiar character they give to the soil in which they are contained. The natural character of a clayey soil is sterility; clay renders a soil stiff, and from its great retention of moisture, in wet seasons it chills plants, and in dry seasons obstructs their vegetation by its hardness. The difference,

however, of clay-lands is prodigious, and some which have this character are extremely fertile: the black and yellow clays are the fittest for corn. Soils of this description should be kept as dry as possible during winter; they should be thoroughly broken by repeated ploughings and harrowings, at seasons in which they are found to be neither very wet nor very dry; they are much benefited by manure, care being taken to employ such as most directly tends to lessen their cohesion and chillness: thus if they be planted with beans, or any plant which thrives in them, and the roots be left to rot in the ground, they will be rendered less cohesive, and even enriched; but gravel, sand, and above all, chalk, lime, and the sweepings of limestone roads, and calcareous marls, effect the most lasting and substantial improvement. When these cannot easily be had, the clay itself, if it can be burnt at a light expense, will be useful, as, by burning, it loses its plasticity, and the application of it in that state would diminish the coldness of the clay. Sometimes the great fault of a clayey soil is the sulphuric acid which it contains in combination with the clay; this may be corrected by wood and peat ashes, and in small inclosures by soap-suds. Beans, wheat, and clover, make a good succession of crops for a clayey soil, which it is found advantageous to dispose in arched ridges, in such a manner that the crown of the ridge may be two feet or more above the bottom of the furrow.

Calcareous, or Chalky Soil.

No single earth will by itself constitute a good soil, but the superabundance of some is much less injurious than that of others. All good soils contain a large proportion of calcareous matter; marls are useful chiefly from the large proportion of it which enters into their composition. Calcareous matter is abundant in the state of rocks, as limestone, marble, &c. but chalk is the usual state in which it exists as an earth. Chalk is easily penetrated by water, and therefore a soil in which it abounds is not easily injured by wet seasons, but it has the disadvantage of becoming hard with dry seasons, although the crops on it do not suffer so much as on most other soils, from a long continuance of hot weather. Lands of this description are much improved by the addition of clay, clayey marl, farm-yard dung, or mould containing a large proportion of vegetable matter: old rags, malt-dust, and the dung left after folding sheep, are applied to it with great advantage, as the nature of this soil greatly tends to reduce such substances to a state favourable to vegetation. Barley, wheat, and oats, thrive on land of this description; saintfoin is well adapted to it, and it

naturally produces a small species of vetch, called the smooth-podded tare, together with poppies, may-weed, &c. Chalky land, on which thistles are observed to thrive, may be considered favourable to the growth of corn.

Sandy Soil.

Of all descriptions of soil, the sandy has the least cohesion, and is the least capable of retaining moisture; it is, therefore, proverbially sterile. It is, however, ploughed and harrowed with far less difficulty and labour than the chalky and clayey sorts of land, and it is well adapted to the growth of bulbous and tap-roots. Heavy rains are apt to wash away a soil of this sort from the roots of plants growing in it; hence, in the improvement of them, care must be taken to increase their cohesion and capacity of retaining moisture, and the use of calcareous marl is of great importance, if the calcareous principle be deficient; but argillaceous marl if there be no want of it. The folding of sheep is extremely beneficial to these lands. The rapidity of vegetation in a sandy soil, is often very favourable to the farmer in affording green food early in spring.

Gravelly Soil.

A gravelly soil consists chiefly of small stones from the size of a pea to that of a walnut, but when a large proportion of the stones are of the latter size or larger, the land is said to be stony. Soils of this description are not washed away from the roots of plants like the sandy, but they have the similar disadvantage of great porosity; moisture easily evaporates from, or sinks through them; hence the vegetables growing upon them often suffer in dry seasons, and the water which they part with so easily, carries along with it a large proportion of the principles which, if retained, would render the soil productive. Beds of gravel are generally either of the calcareous or of the flinty kind; for the former, a clayey marl, and for the latter a calcareous marl or loam, has been found well adapted. As gravelly soils, if in the vicinity of springs, are apt to be wet, chalk is often a useful application to them, to absorb the moisture in winter, and in summer to lessen the effect of the sun in drying them. In the agricultural report of Middlesex, it is observed, that when the bed of gravel is very near the top, a full crop of yellow-blossomed broom covers the ground if in a state of grass, and when ploughed, an equally full crop of sorrel. These signs may therefore indicate the existence of gravel, where it may be of importance to obtain it, for the repair of roads, making mortar, &c. The

common white saxifrage (*saxifraga granulata, Lin.*) is also nearly peculiar to such situations. Gravelly soils easily yield to the plough, and therefore are often brought into cultivation with comparative ease.

Loamy Soil.

The soils called loamy, are composed of all the preceding soils in different proportions, and are farther distinguished by the appellation of clayey, chalky, sandy, or gravelly, according to their predominant ingredient. Hence their value, or the expense of bringing them into cultivation, differs very considerably; their treatment always requires the bad qualities of the predominant ingredient to be checked; but they approach nearer to the proper composition of a soil, than any of those we have yet treated of; they are not apt to produce injurious weeds, or to resist the plough or harrow by too great compactness, nor are they chilled by moisture; they are therefore with less difficulty brought into condition than other soils. It often happens that a loamy soil becomes fruitful after having been merely well broken up and pulverized; exposure to the air renders it fit for vegetation. The deep crumbly loam, which contains much sand, along with a considerable proportion of chalk or calcareous matter, is very favourable to the growth of fruit-trees; and if it be laid in ridges during one winter and the succeeding summer, it will afford ample nourishment to such trees; even though it should have been turned up from the depth of six feet. The loamy soils of the sea-coast are generally fertile, and require little manure; but others are much improved by a supply of animal and vegetable matter, such as farm-yard dung, blood, ground bones, the mud from ditches, ponds, &c.

Peaty and Marshy Soils.

Peaty soils are formed by the deposition and decay of vegetables: sometimes they are left dry for a part of the year, at other times they form a continual morass or swamp. Their value will depend of course on the greater or less difficulty of bringing them into a productive state; and to ascertain how capable they may be of this change, boring must be resorted to in a number of places, if it appear to be necessary. This will show the order of the strata upon which the peat rests, and the method of draining to be resorted to. If a bed of clay be next to the peat, by boring through this, the water will probably sink; if the first solid stratum be a rock, the water must

be carried off by dikes; if the sub-soil is good, or contains materials, such as marl, clay, and gravel, which would correct the spongy soil of the surface, and the moss can be flooded, the surface may in some measure be washed away; but where water cannot be obtained for this purpose, after the draining has been effected, a great improvement will be effected by turning up the good soil, and mixing it with the peat. The expense of this will be comparatively small to that which would be incurred by bringing a suitable soil for the admixture from a distance; the use of lime will produce a further amelioration. If good materials for the improvement cannot be met with on the spot, or brought to it at a moderate expense, paring and burning may be resorted to, especially where the vegetables exhibit large stems and roots, which would be long in decaying. Potatoes have been raised with advantage, as the first crop from peaty or mossy land, especially where the draining has been complete.

Vegetable Soil.

The earth is almost every-where covered with a superficial stratum of loose and friable soil, derived from the decay of vegetables: where the remains of vegetation have long been accumulating, and are mixed with clayey loam and most other earths, they form a compound in which plants in general shoot with vigour. In some cases, however, the vegetable mould may have become too abundant; for grain, a soil purely vegetable would be too light and open; to render such a soil, then, productive for this purpose, quicklime becomes a useful agent, as it hastens the entire dissolution of the vegetable matter, and moss lands have been by its use rendered prodigiously fertile. On the contrary, where the vegetable part of a soil is scanty, it is an excellent practice to turn down the whole of a succulent green crop, and even to plant, for the purpose of affording this supply, such as cover much of the ground, and while growing produce over the soil a stratum of stagnated air. Mordant, in his Complete Steward, asserts that a pound of turnip-seed, sown after harvest, upon an acre of sandy or gravelly, worn-out land, will, if ploughed when at maturity, enrich the land as much as twenty loads of dung.

Miscellaneous Remarks on Soils.

To ascertain the value of a soil, no single method of procedure will suffice; for it has been found that soils, nearly the same, not only in their sensible qualities, but their chemical composition, have been very different in their fertility, and their

fitness for the same kind of produce. A variety of circumstances may be the cause of this, although not easily detected. A greater or less quantity of rain may fall, which requires the soil to be more or less retentive. The tillage may be more or less favourable; a more sheltered or more exposed situation with respect to particular winds, will have its influence; and the greater or less state of subdivision of the same component parts has an important effect. A soil, also, in itself good, may be injured by the alternation of different strata beneath it; if a few inches of it only rest upon clay, or rock, or chalk, it will not be equal to coarser materials resting upon gravel; on the contrary, if a clayey soil rest upon gravel, the coldness and humidity natural to it will be diminished, and its general fertility will exceed expectation, if it is not apt to be drowned by springs. A sandy soil, also, may owe its fertility to a fitness in the under strata for retaining moisture. On the sides of hills and declivities, the soil must be more retentive of moisture than plains, to be equally adapted to the same kind of produce. But, when circumstances like these are duly taken into account, it must be admitted, that chemical analysis is to be placed at the head of all the means which enable us to appreciate a soil: thus if a soil, remarkably fertile in a produce we wish to obtain on other land, contain three-eighths of clay, two-eighths of sand, and three-eighths of calcareous matter, it is obvious that the same composition, if not possessed by the other land, may safely be imitated as nearly as possible. The proportions and component parts just stated, are those which Tillet found best adapted to wheat, in flat countries where a moderate quantity of rain falls. A soil from the low lands of Somersetshire, highly productive in wheat and beans without manure, was found to consist of one-ninth of sand chiefly siliceous, and eight-ninths of calcareous marl tinged with iron; with about five parts in the 100 of vegetable matter.

If the materials can be procured at an expense not too great, too much pains can scarcely be taken to render land fertile without manure; the effects of manure are mostly transient, but when the earth and durable parts of a soil are duly proportioned and combined, the soil attracts large supplies of nourishment for vegetable life from the atmosphere, and thus a lasting source of profit is secured.

Dr. Darwin proposes to dry a few pounds of different soils, in the same temperature; when their moisture is evaporated, they must be weighed, and exposed to a red heat. As carbon is a principal ingredient in calcareous earths, he conjectures that the soil which loses the greatest portion of its weight, is

the most fertile; because the carbonic matter, being the principal nutriment of plants, will be dissipated by the heat.

Another criterion, which will afford useful assistance to ascertain the general character of a soil, is to attend to the state and kind of plants which grow upon it. Where plants adapted only to a peculiar soil, are observed in full luxuriance and abundance, the general character of the soil in which they are thus observed can scarcely be doubted. Thus the fox-glove and sandwort abound in sandy situations; the nettle is most luxuriant on a dry loam; while the rush and brook-lime prefer moist, cold, clayey soils: the common saw-wort indicates a good soil, but the dock an inferior one.

Metallic impregnations, whether as oxides or salts, are injurious to a soil, excepting the oxide of iron, which is beneficial. The oxide of iron is supposed to act partly by its being itself soluble in water, and partly by its affording oxygen to the carbon of the soil, which it thus renders soluble in water, and being itself again oxidized by exposure to the air, it is ready to repeat the same assistance: for it must be observed, that plants draw nothing from a soil but what is held in solution by water, and that water cannot act on carbon before it is converted into carbonic acid by the absorption of oxygen.

On the merits of stony ground, by which is meant ground containing loose stones, which the plough turns out so as to cover a considerable proportion of the surface, the opinion of agriculturists has been much divided; some have contended that the moisture which stones prevent from exhalation and retain near the surface, nourishes the roots of grain especially, and that they are thus beneficial in a much higher degree than injurious from the surface they cover; others are warm advocates for clearing them away. There can be no doubt, that the question ought to be considered in connection with local circumstances: where the soil is stiff and retentive, from the abundance of its argillaceous parts, the stones may certainly be dispensed with; but where, as is commonly the case in stony soils, gravel is abundant and deep, and the soil loose, it will be rather worse than a loss of labour for the land to be more than moderately cleared, especially from flat stones, the size of which but little exceeds that of a hand's breadth. Where it is determined to clear the land of stones, a simple machine may be employed, which will be comparatively quick and easy to the usual method of separating them by hand, or by a common riddle. An axis is mounted on a frame, such as would be made for a grindstone; the axis must lie lengthwise on the top of this frame; at one end of the axis is the handle for turning it, at the other is a conical or bell-shaped riddle, formed

by fastening iron bars to a strong circular piece of wood, united to the axis; these bars are again united at their other extremity by a stout iron rim: the riddle part is therefore formed by the sides of this cone, the mouth of which is twice the width of the base. The bars are so shaped, that the interstices between them are throughout of the same width, or nearly so. While this riddle is whirled round by one person, two others throw in the soil with spades, and those stones which are too large to pass through, are thrown out by the whirling motion into a trench, or in a line with the front of the riddle.

Young observes, "that the sound, mellow, rich, putrid, crumbling, sandy loams, are of all soils the most profitable; such as will admit tillage soon after rain, and do not bake on hot gleams of sun coming after heavy rains, when finely harrowed; such land is better worth forty shillings an acre than many soils deserve five. The next soil is that of the stiff loam, which is nearly allied to brick earth; this, till drained, is generally an unkindly soil, without plenty of manure. It is known in winter, by being very adhesive upon walking over it; is long in drying, even when little or no water is seen upon it; for which reason it is generally late in the spring before it can be ploughed. When quite dry, it breaks up neither so hard and cloddy as mere clay, nor near so crumbly and mellow as the good loam. If it is in stubble, it is apt to be covered with a minute green moss. There are many varieties of this soil, but all agree in most of these circumstances; and in being what the farmers call poor, cold, hungry land. When hollow-ditched, and greatly manured, it yields any thing; but those who hire it should forget neither of these expenses.

"The gravelly soils are numerous in their kind, and very different in their natures. Warm, dry, sound, gravelly loams, are easily distinguished in winter. They admit ploughing all winter through, except in very wet times; always break up in a crumbly state of running mould; and, if in stubble, will dig on trial by the spade in the same manner. If under turnips, you may perceive, by walking through them, that it will bear their being fed off. The wet, cold, spring gravel is a very bad soil; it is known in winter by the wetness of it; and in spring by its binding with hasty showers. It rarely breaks up in a crumbly state, or shows a mellowness under the spade. Very expensive drains greatly correct its ill qualities, but it requires a prodigious quantity of manure to fertilize it. Some gravels are so sharp and burning, that they produce nothing except in wet summers, but such are known at any season of the year. The light sandy loam is likewise an admirable soil: it will bear ploughing like the preceding, all winter long, and appears

quite sound and mellow when tried with the spade. If it lies under a winter fallow, the best way to judge of its richness is to remark the state of the furrows, and the degree of adhesion in the soil. Stiff land being dry and crumbly is a great perfection, and sand being adhesive is an equally good sign. When, therefore, the farmer views a light, sandy loam, whose sound dryness is acknowledged, he may presume the soil is rich, in proportion to its adhesion. If it falls flat in powder, and has no adhesion, it is mere sand. The white chalky farm-land is often cold and wet, will not bear ploughing in winter unless the weather is very dry or frosty, and runs excessively to mortar in a heavy shower when in a pulverized state. It is a cold soil of little profit, except with peculiar management; but answers best when dry, laid down to saintfoin.

"It should be laid down in general as a maxim, that strong, harsh, tenacious clay, though it will yield great crops of wheat, is yet managed at so heavy an expense, that it is usually let for more than it is worth. Much money is not often made on such land. The very contrary soil, a light, poor, dry sand, is very often in the occupation of men who have made fortunes. Some permanent manure is usually below the surface, which answers well to carry on; and sheep, the common stock of such soils, is the most profitable sort he can depend on. All stiff soils are viewed to most advantage in winter: the general fault of them is wetness, which is in the greatest excess at that season of the year. If the fields are level, and the water stands in the land, notwithstanding the furrows are well ploughed and open, it is a sign that the clay is very stiff, and of so adhesive a nature as to contain the water like a dish. It is likewise probable, that draining may prove insufficient to cure the natural evil of such land. This kind of soil likewise shows itself, in the breaking up of stubbles for a fallow; a very strong draught of cattle is then necessary to work it. It breaks up in vast pieces almost as hard as iron. When it is worked fine it will run like mortar, with a heavy spring or summer shower. These soils will yield very great crops of beans and wheat, &c. They must, like others, be cultivated by somebody; but he would advise every friend of his to have nothing to do with them; never to be captivated with seeing large crops upon the land, for he does not see at the same time the expenses at which they are raised.

Inclosing and Fencing.

The general advantages of inclosing land can admit of no question; common-rights are far from either private or public benefits of any value: it cannot be expected that any one will improve the land which belongs to none exclusively; but even supposing uninclosed land to be in the sole possession of one, it will still be in a disadvantageous state. Its full exposure to every vicissitude of weather, renders it comparatively unproductive: the cattle which feed upon it may be hardy, but they will be meagre and small; while the vegetable crops will be scanty, and the most beneficial alternation of them impossible. For different purposes, however, the inclosures should be differently apportioned, and therefore he who has this work to perform, after having taken into view the nature of his soil, and the use to which it is best adapted, must regulate his procedure accordingly.

Cattle are always found to thrive and fatten the most, in warm, sheltered situations; and when not collected in great numbers, they are more quiet, and less apt to injure the fences; therefore, for fattening cattle, small inclosures are the best. The Leicestershire graziers are said to have adopted an opinion, that fifty acres in five inclosures are equal to sixty acres in one. From eight to fifteen acres may in general be considered a proper size for pasturage; but for grain and root crops, the inclosures may be one-third or one-half larger, and the fences neither quite so high or so close, as the free admission of fresh air and sunshine must be studied as well as shelter. It will be necessary not to make the inclosures for different purposes at random, but to place those together, or as near each other as possible, which are to be submitted to the same kind of cultivation. In determining the size of inclosures, regard also should be paid to local circumstances. If the estate be much protected by woods and plantations from the winds most dreaded, the inclosures may safely be larger than when the whole is much exposed; but where the situation is low, and the ground moist, very small inclosures, and high fences, would be the means of too much impeding evaporation, to be advantageous.

The materials of which fences are constructed, must of course vary with the purpose they are intended to serve, and the materials which can be furnished at the least expense. Stone walls, for outside fences, are certainly the best, and in all situations they will generally be preferred where suitable

stone is either supplied by the land itself or can easily be obtained. Their general advantages are, that they can be reared in situations where, from its bleakness, a hedge would be with difficulty brought up and maintained; that they take up little room, do not harbour vermin, weeds, and rubbish; impede hunting, and may be speedily repaired. At the same time, it must be observed, that they serve rather the purpose of dividing, than sheltering land, as the expense of them generally prevents their being built sufficiently high for the latter purpose; and when extensively used over a country, they give it a cold and unpleasing appearance. Stone walls are often built entirely without the use of cement, in which case they are called dry walls; at other times, mud or clay is intermingled with the stones; but the frost soon injures or destroys walls of this description. In other cases lime is used to the outside course, to improve their appearance and strength. Flat stones make the firmest wall, and such as may be made the thinnest, while they least require cement: in the middle of the height of the wall, or at two equal distances, if the wall be high, should be employed stones technically called through-stones, from their passing entirely across the breadth of the wall; and the top of the wall should be laid with stones disposed edgeways; sometimes a covering or sod of turf is added. When free stone is employed, the coping is generally arched or angular like the ridge of a house, to prevent the wall from being walked on, and to carry off rain. Where only the sparing use of lime is admissible, it should be used to the coping, if to no other part.

Stone walls are sometimes only built to the height of two feet, and made up to five feet by turfs or sods. The turfs should be laid so as to break the joints, like brick-work, and the coping should consist of sods placed edgeway, and should overhang the wall a little on each side.

The fences employed for parks, and sometimes for gardens, are generally of paling; which, if made of winter-fallen oak, are very durable. The pales should be cleft thin, and the rails should be triangular, to prevent water from lodging on them. In parks where fallow-deer are kept, it will be sufficient if the pales be 6½ feet high; but where there are red deer, it will be requisite to make them at least a foot higher. The most common kind of wood fence consists of long pieces or stems of young trees, nailed to upright posts; and containing only two or at most three rails; sometimes the timber thus used is hewn, joined by mortise and tenon, and painted, but this is seldom done except near houses. The upright posts of this fence, should be charred before they are driven into the ground,

as no other preparation will effectually preserve them from decay

Hurdles are a moveable kind of fence, constructed somewhat like a gate, and about the same size, but of ordinary timber and workmanship, and with about two or three pointed extremities in each length, in order that they may be struck into the ground at any place required. They are provided as a temporary and speedy means of fencing off any small portion of a field; in order to keep cattle from, or confine them in the inclosure they form. Hurdles are made of the lighter kinds of timber, as alder, hazel, willow, which should be well seasoned.

Another kind of moveable fence has been recently introduced; it is made entirely of iron; it consists of upright pieces or stanchions, which are made of cast iron, and of horizontal rods of malleable iron, about three-quarters of an inch in diameter, and of which there are only two in a height of four feet. Small circular fences, constructed in a similar manner, but entirely of wrought iron, are now often used to preserve single trees from cattle. These fences are neat, and no obstruction to a prospect, but their first cost is heavy. Their durability has not been fully proved.

The fences we have hitherto treated of, are, from their first construction, continually tending to decay: we come now to speak of living fences, which, with moderate care, continue for a long time in a state of progressive improvement, sheltering the pasture and decorating the country. The white-thorn makes an excellent fence, as it grows quickly, is very durable, and makes a handsome appearance. It thrives on almost any soil not very subject to the extremes of wet or dryness, that is not consisting entirely of clay, marsh, sand, or porous gravel. Where it is desired to raise this thorn on wet ground, a ridge of turfs should be raised to plant them in. The sets should be about one third of an inch in diameter, and those which have the greatest number of fibrous roots are the best. They must be planted in autumn. The black thorn is more lasting than the white thorn, and not so liable to be cropped by cattle, but it is not so easily reared, unless the land be rich and dry. It will, however, grow on land too wet for the white-thorn; but its roots are apt to spread much into the land. The sets should be planted in autumn. A ditch should run along the side of hedges, at least three feet wide at the top, two feet and a half deep, and six inches wide at the bottom. Cattle will not be apt to walk in a ditch of this shape: its dimensions must be greater in wet situations.

The holly makes a strong, impervious, and beautiful fence, but is slow in growing; the lateral shoots sould be cropped in the fall of the year. It may be planted with most advantage along with the white-thorn, and as the hollies increase in size, the thorns may be pulled up. Vacancies may be closed, by bending down and covering the lower branches with earth, which will shoot forth the ensuing year. There should at first be three or four thorns for one holly.

In loose, wet ground, willows are proper for a fence, as their roots give stability to the bank. The alder and elder, also suit such situations.

In elevated and exposed situations, the beech and birch make good fences. The former is particularly suitable in places exposed to the sea air, which is injurious to the white-thorn, and most other hedges.

In the first volume of the Letters and Papers of the Bath and West of England Society, is a communication in which elms are recommended for fences. When elm-timber is felled in the spring, the chips made in trimming the trees are to be sown on a piece of newly ploughed land, and harrowed in, as is practised with corn. Every chip that has an eye or bud, will speedily shoot like the cuttings of potatoes; and as such plants have no tap-roots, but strike their fibres horizontally in the richest part of the soil, they will be more vigorous, and may be more easily transplanted, than if they had been raised from seeds, or in any other manner. They possess this farther advantage, that five or six stems will generally rise from the same chip; and after being cut to within three or four inches of the ground, they will multiply their side shoots in proportion, and form a thicker hedge, without running to naked wood, than by any other method hitherto practised: lastly, if they be kept carefully clipped for the first three or four years, they are said to become almost impenetrable.

Whins or common furze make a valuable fence; they are easily raised, and will grow in a soil too scanty, slight, and sandy for any thing else. The best mode of planting them is on a bank, five feet broad on the top, and with a ditch on each side. The surface should then be thickly strewn with furze seeds. When, by the growth of the tree, the stems are left naked and open, a fresh supply of seeds should be thrown in, and only one side of the hedge should be cropped at a time, to admit of which is the use of a broad bank; by this means a good hedge will be maintained. Furze is applicable to a variety of useful purposes in rural economy. When the prickles are bruised, it may be given to cows and horses, and

will be greedily eaten by them. Its blossoms, made into tea, have a salutary effect on the human constitution. It is asserted that durable locks or dam-heads may be raised at one-tenth of the usual expense by the use of furze mixed with the soil behind a thin wall, or even a close paling of two-inch deal boards. Furze is much used for heating ovens; it burns rapidly, emits a great heat, and its ashes afford a ley useful in washing coarse linen.

Where ditches are made to answer the purpose of a fence, they should be five or six feet wide at the top, and from three to four feet deep. The sides must always be sloped towards each other, more or less, according to the liability of the soil to be washed away, and a communication should be formed with some river or brook, to prevent stagnant water.

In connexion with fences, we may say a word respecting gates, which are in fact moveable fences. Cheapness and durability are the chief requisites: cheapness is best consulted by using wood of small dimensions; durability, by using wood well seasoned, well jointed, and disposed in the best manner, for its quantity, to resist strains: neatness is included in durability;—the wood must be painted, or it will soon decay; it must be regularly formed, or it cannot be well jointed. The construction of gates recommended by Charles Westall, in the Transactions of the Society for the Encouragement of Arts, &c. vol. 22, has not perhaps been improved upon: horizontal bars, consisting of wood about three quarters of an inch thick, and three inches broad, are mortised into stout side pieces, and strenthened by two similar bars, which rise from the side pieces at the bottom, and meet at the top bar. To the bars thus disposed in an angle, every other bar is united by a nail or screw-bolt.

When the lower hook of a gate is hung out of the perpendicular, that the gate may shut itself, the inclination should be only just sufficient to effect the purpose, otherwise it forms a force for breaking the gate; and the heavier the gate, the more this adjustment is necessary, as the mischief of acceleration is greater, unless constructed so as not to strike the post, but to vibrate till its force is spent, which is certainly a good precaution.

Stone is the most suitable for gate-posts, but it cannot every-where be obtained; where wood is employed, the part driven into the earth should be charred, and driven deep; the charring should reach a few inches above ground; as all posts decay the soonest at the level of the earth, where the joint action of air and moisture is greatest.

Stiles are constructed for the convenience of foot passengers only; sometimes they are in fact a small gate; sometimes they are regular steps; in stone walls, they are often no more than the projecting ends of large stones, disposed at suitable intervals in a slanting direction: when thus formed, they are not seen at a distance, and such are therefore often used where it is desirable to conceal from strangers the view of a passage or communication. Through a hedge-fence, they often consist of two short ladders, meeting at the top from each side. They will of course be regulated in their form by the fancy of the maker, his views of economy, and the necessities of private or public convenience.

Draining.

Before an attempt is made to drain land, which is either at all seasons a complete bog, or so replete with redundant moisture, during some part of the year, as to be of little value, it is obviously prudential to examine carefully the cause of the wetness, in order that proper means may be resorted to. The water collected upon mountains and elevated grounds, sinks, if the soil is porous enough to admit it, and continues its subterranean course till it meets with a bed of clay or impenetrable stratum. The disposition of the water is to sink perpendicularly; but if the stratum of clay be horizontal, it must either collect as in a reservoir, or come to the surface, in which case it will either flow onward to the lowland in a perceptible stream; or if the earth be sufficiently absorbent to take it up, after spreading over a surface proportionate to its quantity, and the slowness with which it sinks, it will again become obedient to the direction and the permeable or impermeable nature of the strata it meets with. In general, the strata, or different layers of materials of which mountains consist, are not parallel with the horizon, but have the same inclination as the general surface of the mountain itself. If then the water, either at first, or after its second submersion, comes in contact with an inclined bed of clay, it flows over it, and continues its course to the valley or plain below. When the clay does not terminate at the foot of the mountain, the water rises to the surface, and inundates the plain. This is the general cause of boggy land, and it is plain that the land thus inundated, may be drained, by intercepting in its course the water which occasions it. Where the land is suspected to be marshy from this cause. auger holes should be bored at different places along the line where the ground first begins to be too moist, in order to find

the depth of the springs, and consequently the thickness of the upper stratum of the soil. The course of the auger should be at right angles to the inclination of the mountain, as it will then soonest pass through an inclined stratum. If this depth be only a few feet, a ditch should be dug along the bottom of the hill to intercept the water. Should no water appear in the ditch, or but a very trifling quantity, auger holes may be bored in different parts of the bottom of the ditch; when these succeed, many of them should be made, and the water carried off by the nearest water-course. This method of draining marshy ground, seems to have been first practised by Dr. Anderson, of Aberdeen, who states, in the introduction to his "Essays on Agriculture," vol. 3, that he sunk a hole with a wimble into the earth at the bottom of a ditch, in the year 1764; that the water rose rose six feet above the surface of the ground, and has continued flowing ever since, though with diminished rapidity: but Elkington was the person who was first fully aware of the value of the principle, having successfully acted extensively upon it, and obtained a parliamentary grant of one thousand pounds as a reward for the improvement he had introduced.

Another cause of boggy ground, or of the extreme wetness of land, may be a deep and strongly retentive soil, from which the water received has no outlet either through it or over it. In a situation of this kind, when part of the surface of the clay is diffused through the water, and forms a semi-fluid mass, and the matted roots of the grass and other plants adapted to the situation, cover the surface of it, that kind of bog called the shake-bog is formed. In draining a bog of this description, it is proper in the first place to discover at what depth sand and gravel can be met with; and secondly, whether the porous soil, when arrived at, is dry, and fit to let the water drain through, or is itself wet from being incumbent upon clay, and would, but for the superstratum of clay, increase the quantity of water. If it be dry, the course is to dig into it, at a sufficient number of places; or to make one large central opening, to which small drains from all sides must be directed. If it be wet, the drains must be commenced at the lowest extremity of the land, and must be directed towards the nearest river or the sea; and if the land, like the fens of Lincolnshire, is below the level of the river or the sea, machinery must be resorted to for drawing it off. If there be any appearance of a stream from the morass, the draining should be commenced at that spot, by which a large tract of land may often be cleared immediately.

The two sources of boggy ground above pointed out, either

separately or combined, or modified by various differences in the depth, extent, or want of uniformity of the gravelly or clayey strata, form all the kinds that exist. The strata of a valley are generally the same, and disposed in the same order, as those of the mountains rising from it; but the superficial strata frequently terminate without attaining the top of the mountain; hence the water from the top may frequently get under one or more beds of clay, and will of course, at the bottom of the hill, be at a great depth, perhaps too deep to be reached without considerable trouble; and yet a trench, or a well dug there, will finally be successful, although it may pass through one or more beds of clay. But when the water cannot be intercepted, it must be drawn off by deep drains made across the morass, as in the case just mentioned of the morass, where clay, gravel, and clay, alternate, so that the water cannot be caused to sink.

As an accurate knowledge of the strata of boggy land and its neighbourhood, is of so much consequence in forming a judgment of the best means of draining, a careful attention should be paid to every indication of their nature. This object may often be pursued without expense. The beds of the nearest rivers, and of the steep parts of their banks, may be examined, as also pits, wells, and quarries, which may be in the neighbourhood.

In general the object of draining cannot be completely effected, without having one or more main drains across the morass, with others in all directions, that discharge themselves into it: and as this labour is performed with great expense, it becomes important to fix upon the best plan of keeping them constantly open, to render the renewal of it unnecessary. Different soils are more or less favourable to the work, and some land, a peat bog, for example, is sometimes so suddenly and completely drained as to be difficult to plough or dig, a fault which must be guarded against. In all lands, however, it is a rule, to slope the sides of the ditch towards each other, so that if three feet wide at the top, they will scarcely be one foot at the bottom. Their depth may vary from two feet to two feet and a half, or even three feet, according to circumstances. Thick ropes of twisted straw may then be laid in the trench, or loose stones, or a quantity of the black or white thorn, or small faggots of willow, alder, &c. may be laid at the bottom and covered with thorns, and lastly, these must be covered with turfs, having the grass side down. The wood used for these purposes should always be in its green state, as it will be the most durable when thus used. Where flat stones can be procured for forming the sides of a drain, all other materials

are superseded: one flat stone should be laid along the bottom, and two others should be placed in an angle, so as to meet over the middle of it at the top; on the contrary, when wood, straw, &c. is used for filling a drain, the narrowest part should be at the bottom.

A very simple mode of draining land, which is wet merely from the retentive nature of the soil, and which has been practised with success, consists in adding to the felly of a six-inch cart-wheel, a piece of wood, upon which is a triangular rim of iron. That side of the cart containing this prepared wheel, is then loaded, till the piece of iron indents the soil to the depth of six or eight inches. These furrows are made in lines from five to ten yards asunder, the grass is merely pressed down, and not destroyed, and they generally grow up in the course of the year. They should therefore be made annually, at the approach of winter, but the work is so easily executed, that a single person with two old horses, will go over from ten to twenty acres in eight hours.

It is common for the land which has been drained, to want solidity; to remove this fault, it should be rolled.

Irrigation.

Next to the advantage of draining land which is too wet, must be placed that of supplying it with the moisture of which it is in want, and the practice of which is called *irrigation*. Lands are frequently so situated that a stream of water may be conveyed over them at any time, and the effect produced by the judicious use of such means, in hastening vegetation, is often equal to a guinea an acre, merely for the feeding between March and May. No method of improving land brings a more immediate remuneration. The soils most essentially benefited by irrigation are those where sand and gravel prevails.

To secure the full advantages of irrigation, the water must be completely under command. After it has been ascertained that it can be admitted upon the land, the next question is, whether it can be completely and immediately drawn off. To determine this point, the fall must be examined by levelling; if it is equal to fifteen inches per mile, the irrigation may be adventured on; but if it amounts to two feet or thirty inches in a mile it will be still better, as the lively motion of the water is desirable, and its stagnation, or any near approach to that state, is to be dreaded. The quantity of water which can be

commanded must also be considered, in order that the irrigation of no more land may be attempted at once than it will supply.

Two modes of irrigation are in use: the first consists in carrying the water through the land in small channels like drains. The advantages gained by this practice consist, partly in what the soil extracts from the stream by its sponginess, and partly in what it gains by the channels being so proportioned to the supply of water, that they overflow their banks. The channels must be continued by pipes and trunks, across ditches and under roads. This plan is evidently adapted to make the most of a small supply of water.

The second method consists in laying the whole surface of the ground under water. This is the most effectual plan, and often the easiest to execute. The water must be carried off by drains previously prepared.

The time of the year in which irrigation may be performed to most advantage, is from October to the beginning of April. As the spring advances, land requires less water, it should remain on for a shorter time, and the intervals between the waterings should be longer. If the water has remained on the land too long, a white scum will be more or less observed in places where it has stagnated, and the warmer the season, the sooner this will occur. It proceeds from the rotting of the grass, and should never be waited for. In the last three months of the year, the land will bear soaking for twenty successive days, but in March or April not more than two or three days. In some parts, the lands are laid wet and dry for alternate weeks. Upon the whole, perhaps it may be well to make the time of watering before February, twice as long as the draining; and after that month, the draining may be twice the length of the watering.

The water brought upon land by irrigation, does not benefit it solely by the moisture it supplies. The mud which it brings along with it consolidates swampy ground, while it enriches the sandy and gravelly. To obtain the greatest quantity of mud, the river or source of supply should, if convenient, be opened to the bottom, and frequently stirred up. For the same reason, irrigation continued during floods is eminently fertilizing. The water which has flowed through a fertile country, also, is more beneficial than that which comes from a mountainous barren district. Calcareous impregnations are very fertilizing, while those containing metallic salts are injurious. In spring, if sheep be fed upon the land which has been irrigated, they quickly improve and fatten; but in autumn they must always be kept off the grass of land irri-

gated during the summer, as it would give them the rot. In spring, however, sheep and calves are the fittest animals to turn upon irrigated land, as the larger kinds poach it, and injure the trenches.

MANURE.

The substances employed to augment the fertility of land, by intermixture with the soil, are called manures, whether they operate directly, by affording the pabulum of vegetable life; or indirectly, by a chemical action which causes other substances to afford this nutriment, or a mechanical action that gives to the soil a texture better adapted to vegetation. Hence, scarcely any substances exist, whether solid or fluid, which may not be applied as manures, if sufficiently plentiful; we shall briefly treat of the most general and useful.

Animal Manures.

When animals are deprived of life, all their muscular and soft parts rapidly putrefy, and as the elements composing them are the same with those of vegetables, and become during putrefaction soluble in water, they form a very valuable class of manures.

Fish, &c.

The most abundant supply of animal remains, which can be obtained for the purpose of manure, consists of fish, such as herrings, pilchards, muscles, mackarel, the supply of which at the proper season, can generally be extended far beyond what is required for food. They should be mixed with lime, to hasten their complete destruction, and to prevent the stench which might otherwise arise. Used in the proportion of twenty bushels to an acre, they will have an excellent effect. The offal and refuse of slaughter-houses and butchers' shops, used in a similar manner, are equally beneficial.

Chandlers' Graves and the Waste of Manufactories.

Chandlers' graves, which is the refuse in the manufacture of candles, forms a very valuable manure; as also the scum

formed in refining sugar, and which consists of lime and bullocks' blood.

The clippings and waste scraps of furriers, fell-mongers, curriers, and others who deal in skins, are well suited to land intended for wheat or barley, especially where the soil is light and dry. They should be scattered on the ground just before seed time, and used in the proportion of two or three quarters to an acre, and should be ploughed in, to prevent their being consumed by crows, or other animals.

Woollen Rags.

Woollen rags may be frequently obtained in abundance in the vicinity of paper-mills, and large quantities could be collected by those who take in linen rags, for the supply of paper-makers. They should be reduced to scraps in a paper-mill, and strewed by hand, for wheat and barley, three months before the sowing season; from six hundred weight to half a ton per acre is generally used. In Kent, a ton weight per acre is laid on every third year for hops. Dry gravelly and chalky soils are most benefited by them.

Hair, feathers, and similar substances, have the same properties as wool, when used as manures.

Bones, Hoofs, &c.

The bones, hoofs, and horns of animals, are valuable manures, and as their effects keep pace only with their decomposition, they are observable through a course of many years. In general, unless ground to powder, their best effect is not considerable the first year, although an improvement will be observable. Bones should be ground in a mill, similar to that used by tanners for grinding bark, or broken by a large hammer moved by water. The hammer need not be very heavy, but it should have grooves crossing each other on its face, to prevent the bones from slipping aside. It should strike upon a surface of iron, on a level with and close to which should be a grating, that will only suffer pieces of the proper size to pass through it. While the hammer is in motion, a man stands by to supply the bones as they are required, and at the rising of the hammer, before it again falls, he pushes upon the grating with a rake, the bones which have been struck, and draws back those which do not pass through. The bones should be reduced to pieces not larger than hazel-nuts.

The bones of fat cattle are better than those of lean; and bones should never be burnt, as that operation would destroy their gelatine and ammonia, upon the extrication of which their value almost entirely depends. Bones will improve every kind of soil, but are most effective upon those which contain at least a moderate proportion of vegetable remains. From thirty to sixty bushels of bones may be used to each acre; the grass lands thus treated will in spring be fit for the nourishment of cattle several weeks before any other.

Farm Yard Dung

The chief dependence of the farmer, for animal manures, is on the supply derived from the larger kinds of domesticated animals during life. It has been fully proved, that the dung of fat animals is of a much more enriching quality than that of lean ones, and that it varies considerably, not only with the condition of the animal, but the food it consumes. Horses liberally supplied with corn, yield a more valuable dung than when fed upon hay and grass. Animals fed upon oily seeds, such as lint and rape, afford a manure of the most fertilizing kind.

Too little care is generally taken in farm-yards to prevent the waste of manure; it is of little comparative value, until fermented along with the straw carried out along with it from the stable; it should therefore neither be suffered to lie spread out thin in the farm-yard, nor carried directly and laid out upon the land: Dr. Darwin proposes to place the heap of dung upon a gently rising eminence, with a basin beneath, in order that the superfluous fluid, which would prevent the fermentation of the straw, may drain off and be collected. If weeds, leaves, saw-dust, or any vegetable or animal matters, be thrown into the basin, they will contribute to form an additional quantity of manure; or as the liquor consists chiefly of urine, which of itself is a very valuable manure, it may be used alone to the land, or mixed with the dung, when it is duly fermented and ready to be carted away. The dung-heap should never be less than four or five feet deep. The prudent farmer should always aim at producing the greatest possible quantity of dung upon his own premises, by using in litter all the corn that he grows.

Night-soil produces a surprisingly fertilizing effect, for the first year; but in the second year its effects are not so obvious, and in the third year they disappear. The opinion of the bad taste it communicates to esculent plants is ridiculous; on the contrary, the vegetables grown upon lands on which it has been spread, are luxuriant and healthy without rankness.

Swine's dung is justly prized by the farmer; it has been applied with singular advantage to apple, pear, and other fruit-trees. The dung of rabbits, pigeons, and poultry, is suitable for arable lands of a cold clayey nature; but as it is extremely hot, it is best applied in winter, when the rains will be likely to wash it into the soil; if laid on in spring, and the ensuing season should be dry, it might prove injurious. It has been remarked that cattle are much disposed to fatten on lands to which goose-dung has been used.

The dung and urine of sheep are applied to land by folding these animals upon it, and they greatly improve a light sandy soil.

Vegetable Manures.

The remains of the soft parts of animals, as well as their dung, and other animalized substances, are, by the process of putrefaction, so entirely resolved into substances which are either taken up by the air, or rendered soluble in water, that in the course of a shorter or longer period, scarcely a trace of them is to be discovered in the soil to which they have been applied. They therefore make to soils no permanent addition of any consequence. In this respect they differ considerably from vegetables; of these, the principal part of the bulk consists of carbon, only a portion of which is rendered soluble in water by putrefaction; the remainder, under fresh accessions of this kind of manure, accumulates till it essentially modifies the soil upon which it is laid, or until a soil of a distinct species is formed on the surface of the earth.

The more succulent plants are, and the more they contain of saccharine and mucilaginous juices, the more readily they putrefy and are converted into manures, and the smaller in quantity is the part that permanently remains in the soil. This arises from their containing less carbon than the plants of a ligneous texture, and as such plants are very plentiful, instead of being thrown away, they may be converted into manure with great advantage. Thus dock-roots, cabbage-stalks, and weeds in general, if laid in heaps, and covered over with earth, and especially if every stratum of a foot in thickness, be sprinkled with lime, will speedily ferment, and form a valuable compost. In dry seasons, or when dry plants, such as fern, rushes, &c. are largely employed, it will accelerate the putrefaction to moisten the heap, and not to press them very closely together.

Sea-weed.—River and Pond Weeds.

Sea-weed forms a valuable manure to the farmer who can obtain it within a moderate distance; that which is separated from rocks is better than what is thrown up by the tides. It may be applied to land immediately on its being gathered, as it speedily putrefies; or if wished to be reserved, it should be disposed, in alternate layers with mould, along with a small ouantity of lime.

River and pond weeds will improve a sandy soil, and prepare it for turnips or wheat, if from ten to fourteen loads per acre be employed.

Green Crops.

The plan of growing green crops, for the purpose of turning them down, or ploughing them into the soil, has not been much practised; but it is well adapted to lands in want of vegetable soil; vetches, turnips, beans, buck-wheat, and rape, are suitable for this purpose.

Ashes.

The ashes of fern, stubble, and peat, form a valuable manure; but as the quantity of ashes is so much smaller than what the materials affording them would yield by their putrefaction, it is only for particular purposes that it becomes expedient to obtain them; such as destroying the sourness of a soil, and to gain time, by reducing rushes and similar weeds to the state of manure more rapidly than any other means will accomplish. Peat is burnt like charcoal, under a covering of turf.

Tanners' Waste.

The bark of oak, or tanners' waste, when completely putrefied, which may be effected by adding lime to it, and suffering it to remain in heaps kept moist, greatly improves cold, stiff, heavy soils. If intended for grass lands, it should be laid on early in autumn, that it may be washed in by the rain, as it is too heating to be left on lands during a season which may probably be dry. When designed for corn-fields, it may be spread immediately before the last ploughing, in order to be turned down, and brought into contact with the roots of the corn. In this way, its effect will be slower than when lying on the surface; but it is necessary to guard against a very early vegetation, which might be injurious, should a frost occur in spring.

Rape Dust.—Rape Cake.—Malt Dust.

Rape-dust, rape-cake, and all oleaginous substances, are useful manures, but they can only occasionally be obtained at a cheap rate and in sufficient quantity.

Malt-dust, sown along with grain, in the proportion of 80 bushels per acre for wheat, and 60 bushels for barley and for grass lands, is extremely beneficial to clayey soils or stiff loams, particularly if laid on just before rain.

FOSSIL MANURES.

Fossil manures, or those derived from the mineral kingdom, are very numerous, and from the fixedness generally belonging to this class of bodies, most of them form a permanent addition to the soils upon which they are applied.

Lime.

Lime is one of the most valuable and active manures of this class, for stiff soils which are deficient in the calcareous in gredient; also for the sandy, and for those which contain a large proportion of unreduced vegetable matter, such as peaty and moss lands, and waste land generally. It rapidly converts dead vegetables into soil, and is very efficacious in destroying insects, thus at once preventing their depredations, and fer tilizing the soil by their remains.

Lime, after having been carted from the kiln, should be laid in heaps where it is to be spread, moistened with water, and left covered with earth, till perfectly slaked. It is the more useful, the more perfectly it is mixed with the soil; it should not therefore be suffered to be long in its slaked condition, as it will become full of clots which will not afterwards fall into powder. During winter, it is improper to lay it on, particularly when the land is on a declivity, as the rains of that season might wash much of it away. It should be spread and ploughed in immediately before sowing. The quantity to be used differs with circumstances. On strong clays, particularly if soured by the presence of an acid, 400 bushels per acre will not be too much. On soils where the object is to convert vegetable matter into soil, 200 bushels per acre will suffice.

On poor, light, and thin soils, and on stony land, lime is of little service; but where it is proper, it has been observed, that the grain produced by lands which have been limed, has

a thinner skin, and yields more flour, than the produce of other lands. The reason of this is supposed to be, that it contains more starch and less mucilage; the lime tending to hasten the ripening of the seed, and to convert mucilage into starch.

It is the common calcareous limestone, to the qualities of which, what we have hitherto said refers; but some districts contain chiefly magnesian limestone, which is very injurious to vegetation. The difference between the two kinds was first made known by Tennant, in 1799, and the discovery settled the perplexity which had arisen with respect to the use of lime; those who used only the limestone now known to be magnesian, finding that they injured themselves by it, while others, who had no other than calcareous lime, disputed the possibility of such a result. Magnesian limestone is generally of a yellowish brown or fawn colour, but a more certain criterion of it is, that it is ten times as long in dissolving in an acid as common limestone.

Chalk.

Chalk is converted into lime, by exposure to a red heat, but it is generally applied to land in its unburned state, in which case the only difference between it and slaked lime, is, that the lime contains a less proportion of carbonic acid, and is therefore more acrid. Hence chalk is applicable to lands of the same description as require lime, but an equal quantity of it is not so efficacious, not only because it is less operative in hastening the dissolution of vegetable matter, but because it cannot, at any admissible expense, be reduced to powder and intimately combined with the soil. The quantity of it used, may be from one-third to one-half greater than that of lime. It is particularly beneficial to land injured by the vicinity of springs. The whitest and hardest chalk is the best. It should be laid on against winter, in order that the frost, by pulverizing it, may hasten its blending with the soil.

Marl.

Marl forms a very valuable manure, if it be of a proper kind for the land to which it is applied. It is of three kinds; viz. calcareous, argillaceous, and sandy.

Calcareous marl consists of from thirty-three to eighty parts of chalk, or calcareous earth, and from sixty-seven to twenty parts of clay in the hundred. It is generally of a yellowish white, or yellowish brown, but in some places it is of a brown

or reddish cast. That which contains shells is most valued, and is called shell-marl. It effervesces with acids; when pulverized, it feels dry between the fingers, and if immersed in water, it readily crumbles to pieces; but does not form a viscid mass. It is commonly discovered a few feet beneath the surface of the soil, and on the sides of hills, or the banks of rivers flowing through calcareous countries.

Argillaceous marl contains from sixty-eight to eighty parts in the hundred of clay, and from thirty-two to twenty of chalk. It is of a gray, bluish brown, or reddish-brown colour. It is harder and more unctuous than the last species, and if exposed to the air or moisture, it does not moulder so quickly. It effervesces with the mineral acids, but not with vinegar.

Siliceous or sandy marl, contains a greater proportion of sand than of chalk or clay. It is of a brownish gray or lead-colour, and is in general friable and flaky, though it sometimes occurs in hard lumps.

Heavy clay soils are most benefited by calcareous marl; the sandy, gravelly, and light loamy soils, by argillaceous marl; siliceous marl may be applied to the same kind of soil as the calcareous, where the calcareous cannot be obtained.

Much of the utility of marling depends upon the marl being intimately combined with the soil. This dressing should therefore be given in summer, when the marl is light, dry, and easily crumbled, and the marl suffered to lie on the surface during the ensuing winter, as the alternation of frost and rain will tend to complete its pulverization. The quantity of marl to be used depends on the state of the land to which it is intended to be applied; but it is advisable to err rather by using too little than too much, as it is not easily removed. Twenty tons per acre is in general a proper quantity, excepting for grass land, where half as much, thinly and evenly spread, will generally suffice.

When land has been properly marled, it will continue in good condition for twelve or fourteen years.

Gypsum.

Gypsum, or the stone from which plaster of Paris is prepared, has not in this country been fully tried as a manure. In America it is extensively used with the greatest success. It is ground by a mill and sifted, and is then scattered on the land in the proportion of eight or nine bushels to an acre, at any season of the year. It powerfully accelerates the putrefaction of vegetable and animal matter, and is well adapted to increase the crops of grass, saintfoin, and clover.

Clay.

Clay greatly improves a sandy loose soil, and the greater the proportion of silex in the sand, the more advantageous it will be. In estimating the expense of it, the durable nature of the change it produces must be attended to; a good claying will be efficient for almost half a century. In the North Riding of Yorkshire, land so sandy as to produce with any other manure only rye, will, with clay, yield plentiful crops of oats, barley, &c. The usual quantity laid on, is from ten to twelve loads per acre.

Burnt clay, reduced to powder, has the opposite properties of clay itself, and improves cold, wet, stiff, clayey soils.

Sand.

For clayey soils, moorish tracts, and stiff loams, sand forms a useful dressing. Sea sand is the best; the clays and loams will often take from 40 to 50 loads per acre; but moorish soils will require two or three times that quantity.

Coal Ashes

Coal ashes form a useful manure for lands of the description requiring burnt clay. They may likewise be employed as a top dressing for clover, on dry, chalky lands, over which they ought to be scattered in the months of March and April, in the proportion of from 50 to 60 bushels per acre. They may also be applied in like manner to grass lands.

Soot.

Soot remarkably increases the produce of soils abounding with vegetable matter; it prevents the growth of moss; and from its warmth, makes an excellent addition to cold, moist, and clayey meadows and pastures. The quantity used varies from 15 to 25 and even 40 bushels per acre. It should be strewed on the land in calm weather during winter, so that the subsequent rains may wash it into the soil, as in spring the heat it would produce, might be a check upon vegetation. It is often employed as a top-dressing to grain and grass, and on the former, has been found extremely useful in destroying the wire-worm and other insects.

It is sometimes a condition in leases, that no more soot shall be used on the farm, than is produced upon it; and as a reason for this, an opinion has prevailed, that soot, though it greatly increases the quantity of produce, during the first year

after its application, yet it exhausts the land, which is afterwards in a worse condition than if it had not been employed. The conditions of leases are often irrational, and injurious both to farmer and land-owner; it deserves inquiry whether this is well founded.

Saline Manures.

Saline manures in general combine readily with other substances, and produce decompositions which are extremely useful to agriculture; but it is more necessary than with other kinds of manure, to guard against using them in excess, particularly when they contain a powerful mineral acid, as in the first substance mentioned below.

Manures of this kind are chiefly useful when the soil contains much vegetable or animal matter.

Salt.

Salt, as a manure, is singularly beneficial, if used in small quantity. The fattening of cattle upon salt-marshes, has been practised time out of mind, and it is to the salt contained in those lands that a very considerable part of the effect must be attributed.

Salt is of great use for raising turnips, and also for corn, of which it causes the straw to be strong, and the grain thin hulled and heavy. It sweetens sour pastures; improves and increases the herbage; while it destroys noxious insects.

The quantity of salt which has been recommended, is from twelve to sixteen bushels per acre; but on the authority of a gentleman, who had made through a course of years a great number of experiments on the use of salt as a manure, and who communicated the result of them to Parkes, the ingenious author of the "Chemical Catechism," *one* bushel per acre is all that can be used with safety: a greater quantity would render the land sterile for two or three years afterwards. This is consonant with the fact, that a small quantity of salt hastens putrefaction, while a large quantity effectually prevents it: for the salt does not act so much by its being imbibed by the plant, as by its property of attracting moisture from the atmosphere, promoting the decomposition of other substances, and causing them to afford the nutriment required.

Edmund Cartwright, of Woburn, received from the Board of Agriculture, the honorary reward of a gold medal, for a

valuable set of experiments made by him, to ascertain the value of salt in agriculture. Of the soil he used, nearly three-fourths was sand, the remainder consisted of calcareous and vegetable matter, with alumine, and a small quantity of oxide of iron. Having tried all the usual manures, alone, and differently combined, he found salt to be superior to any of them, when used singly, excepting chandlers' graves; but of mixed manures, salt and soot were superior to all others. The produce upon which these experiments were made, was potatoes; and it was observed, that whenever salt was used, this root was free from the scabbiness with which it is commonly infected. One peck of soot, and a quarter of a peck of salt, were used to a bed one yard wide, and forty yards long. When the salt was used alone, the quantity was the same to a bed of the same extent.

Saline Refuse of Manufactories.

Chandlers' graves, it has been noted above, is an excellent manure; proving superior to salt when used alone; the refuse of salt-works, soap-boilers, bleachers' waste, may also afford the farmer an equally valuable resource.

FLUID MANURES.

Sea Water, &c.

The tracts of land called the salt-marshes, are occasionally overflowed by the sea, and the nourishing herbage which this natural irrigation produces, evinces in so remarkable a manner the utility of sea-water as a manure, that those who have lands on the sea-coast, should not suffer it to escape their attention. Probably to the animal and vegetable matter with which the sea-water is charged, may be attributed some of its fertilizing properties.

For the utility of common water as a manure, we refer to the section on Irrigation.

The liquor of the farm-yard should never be allowed to run to waste, as whether used alone, or mixed up with composts, it is one of the most valuable manures.

The mud derived from the sweepings of streets, ponds, and ditches, may generally be used with advantage; but its composition should first be taken into consideration; sometimes clay, sometimes siliceous sand; sometimes calcareous, sometimes vegetable matter, is the predominant ingredient; and it is sufficiently obvious that it must be used accordingly

Oil Compost.

Dr. Hunter invented a fluid manure, or oil-compost, which is prepared as follows; 12 pounds of North American potash are to be dissolved in 4 gallons of water. After the solution has stood 48 hours, 14 gallons of train-oil are to be added to it. In a few days the mixture will have become nearly uniform; it may then be poured on 14 bushels of sand, or 20 of dry mould, and the whole should be frequently turned over, for the space of six months. When used, it is mixed with one or two hogsheads of water, and conveyed upon the land by a water-cart. This oil-compost is a valuable manure; but the inventor admits its inferiority to rotten dung.

MISCELLANEOUS REMARKS.

For land which has been long kept in good condition, a sufficiency of animal and vegetable manure may, under judicious management, generally be produced on the premises to continue its excellence, and even to improve it: but when a considerable capital is to be devoted to produce a spirited and immediate improvement of poor and much-neglected land, the product of the yard can afford no adequate supply. In this situation, much may be gained or lost by the procedure adopted. Some slight acquaintance at least with chemistry, or of the action of substances on each other, will be extremely serviceable; to be unqualified in this respect, will be labouring in the dark: a successful result may be obtained, but it will be very imperfectly known how it happened; and it will afford no valuable instruction for the direction of the future. When the surface-soil of the estate is known, the under strata must be examined, to discover whether earthy materials of value can be obtained on the spot; attentive observation must be employed to discover whether manufactories, established within a moderate distance, afford refuse, which may be used alone, or is fitted to render other cheap materials efficacious. Then the manure supplied by the neighbouring towns, roads, and other usual sources, must be examined; thus the sweepings of roads and streets paved with limestone, will be valuable to land deficient in calcareous matter; and the fuel used in the district, which may be either of vegetable or mineral origin, will make a considerable difference in the dung-hills. It can scarcely need remark, that in estimating the value of any manure, its first cost and probable durability must be conjoined. By a vigilant and early attention to all local circum-

stances, very efficacious materials may often be collected at a moderate expense. The only general advice which can be given, is, to revert to the action of manures, which ameliorate soils from four different causes:

1st. They reduce them to a proper tenacity; when this is effected, the plants are properly supported, their roots shoot in the manner to which they are naturally disposed, and they are in a situation to receive the nourishment they require.

2ndly. They nourish plants, because, during putrefaction, they become in part soluble in water, and the water thus impregnated, is taken up by the roots, and becomes a part of the substance of the plants which receive it.

3dly. They contribute to the nourishment of the plant, by hastening the putrefaction of animal and vegetable bodies, and by decomposing earths; such as taking carbon from carbonate of lime.

4thly. They contribute to the growth of plants by the warmth they produce, which is a collateral effect of decomposition.

Earthy additions to a soil, produce in the greatest degree, and chiefly, the first-mentioned effect of manures; fermented animal and vegetable bodies the second; saline bodies the third; animal, vegetable, and saline substances, all produce the fourth; but in those which are either wholly or chiefly vegetable, it is the strongest: and the effect of composts and much compounded manures will generally be proportionate to the degree in which they partake of the properties of each of these classes.

In heaping together materials for the formation of compost, regard must be paid to the activity with which the substances will act on each other. Thus if caustic, that is, fresh-burnt-lime, be mixed with farm-yard dung already nearly decayed, the consequence will be rather worse than labour lost; for the violent action of the lime will presently effect the entire dissolution of the dung, and its most valuable parts will be converted into gas, and dissipated, leaving only a dry compound, of little comparative value. Caustic lime is fittest for coarse materials, or plants having strong stems, and many ligneous fibres. Well slacked lime, or chalk, and only in a moderate quantity, should be mixed with substances already hastening to dissolution. The fermentation of substances, or their action on each other, is as much as possible to be brought just to such a state, that it will go on, after the manure is buried in the soil by the plough.

Of Paring and Burning.

The production of manure, by paring and burning, on the spot where it is to be used, is not at present a very common practice. It is employed for lands which are intended to be brought from a state of nature or waste into cultivation. It consists in cutting off the turf, and piling it in heaps to dry; when perfectly dry, it is burned to ashes, which are spread upon the surface from which the turf was taken, and ploughed in. Rushy, heathy, and barren lands, have been by these means rendered very productive; but if the quantity of vegetable matter left in the soil, is not considerable, the land will not bear this operation, and will in a season or two return to its original poverty, unless the soil be clayey, when the burning is beneficial, to furnish a manure which will lessen its coldness and wetness. A few large fires, are not so beneficial as a great number of small ones, by which the whole surface of the ground is warmed.

Paring and burning form together rather an expensive operation, which should only be resorted to, where the quantity of vegetable soil is considerable, and where lime cannot be obtained at a rate sufficiently cheap, to reduce it into mould. The preparation effected by it is excellent for turnips and potatoes.

Of Fallowing.

Fallowing consists in allowing .and to remain for a season in an unproductive state, in order to prepare it more effectually for bearing a large crop. It affords an opportunity for checking the errors of bad management, by which the land has been far exhausted, or is too replete with weeds to be fit for the reception of valuable seed; this is effected by repeated ploughings and harrowings, thus pulverizing the soil, destroying and intimately blending with it the weeds with which it was overrun, and exposing new surfaces to the ameliorating action of the sun, air, rain, and dews. It is only as a preparation for white crops that fallowing is adopted, and under a good system of management, it is not necessary for this purpose. It is oftenest required by a heavy, clayey soil.

Fallowing may be undertaken either in winter or summer, according to the state of the soil, or the crop to be raised. If

the land is to be prepared for barley, the fallowing must be accomplished during winter, and therefore if the soil be clayey, ploughing and harrowing should be at least once performed in autumn, before the wet weather commences, otherwise the heaviness of the work will render it very expensive. If a summer fallow is designed for a clayey soil, as a preparation for wheat, the ploughing should be undertaken before the soil gets too dry, for the same reason, of doing it when the labour will be least.

Although the necessity of frequent fallows, to destroy weeds, is a reproach to a farmer, yet where fallowing has become necessary, it ought decisively to be undertaken. Fallowing sometimes supersedes the use of manure for the crop immediately following it; and then if manure be used to the second crop, both will be abundant.

Green crops, called fallow crops, which are intended to relieve the land by difference of produce, and thus render naked fallowing unnecessary, have been adopted with the greatest success. Thus on heavy land, instead of a summer's fallow, beans, pease, cabbages, red clover, tares, and rape, are recommended; and on light soils, potatoes, turnips, and buckwheat if the land be good. The hoeing and preparation of the land for these crops, secure in a considerable degree the pulverization and exposure to the air which are among the chief advantages of fallowing, and the plants, when grown up, shelter the land from much of that loss by evaporation which fallowing occasions.

OF THE DIFFERENT KINDS OF CULTIVATION, PRODUCE, AND LIVE STOCK.

Of the Culture of Grasses

Grass lands are required for two purposes; first, for affording hay, and when devoted to this use they are properly called *meadows*; secondly, for the growing herbage to support cattle, in which state they are called *pastures*.

The greater or less extent of the portions of an estate devoted to pasturage or meadow produce, must often be determined by local circumstances. Low and wet tracts of land produce a great abundance of high grass, but it is coarse; elevated and dry tracts, on the contrary, yield a fine, sweet, but low herbage, which renders the flesh of cattle extremely delicate.

Cattle are generally suffered to crop the early, as well as the after grass of meadows; but they should never be suffered to remain on the land, at a time when, from its wetness, they would be apt to poach it; as every spot on which they might tread would become a receptacle for water, and would not be restored to a state of bearing grass, for several years afterwards. Every precaution should be taken to preserve on meadow lands a smooth surface, in order to render the operation of mowing easy and perfect. The rolling of such lands early in spring, especially if they have been irrigated, is also useful to destroy ant-hills, check the growth of weeds, and to make a close thick sward, for every branch of clover, which is closely pressed to the ground, takes root again.

When ploughed lands are to be laid down for meadow or pasture, too much pains can scarcely be taken to pulverize the soil thoroughly, by ploughing and subsequent harrowings, in order to render the surface fine and clean. The grass seeds may be sown either in summer or winter, after turnips, cabbages, or any hoeing crop, but it should be in damp weather. On the approach of winter, the young crop should be slightly covered with long stable dung, old thatch, sand, earth, or any other manure. The weeds should occasionally be removed, and vacant spots replenished with seed. Of grain-seed it is easy to sow too much, but grass seeds can scarcely be sown too thickly on any soil, although bleak situations and infertile ground require still more seed than others.

A really good turf is formed with so much difficulty, that when once produced, it should never be broken up, without a full consideration of the advantage to be gained by the change.

Poor pastures and meadows are greatly improved by folding sheep upon them, for these animals eat almost indiscriminately every thing young and tender, and thus consume a number of weeds; their manure also is of the most beneficial kind, and their close cropping tends to produce in the grass the desirable state of matting its roots.

Light top-dressings of quicklime, are well suited to grass lands, where more moss is to be destroyed; but in general, lime mixed with earth, or the mud of ditches and ponds, is preferable: soot also makes a good top-dressing.

An eminent agriculturalist has given the following arrangement of grasses adapted to the different sorts of soil:

Clay.

Cow
Cock's-foot
Dog's-tail
Meadow fescue
Foxtail
Rough-stalked meadow
Oat
Trefoil
Yorkshire white
Timothy.

Loam.

White clover
Rye
Meadow fescue
Foxtail
Dog's-tail
Common meadow
Yorkshire white
Timothy
Smooth-stalked meadow
Sheep's fescue
Hard fescue
Yarrow
Lucerne

Sand.

White clover
Rye
Yorkshire white
Sweet-scented vernal
Sheep's fescue
Yarrow
Burnet
Trefoil
Rib.

Chalk

Yarrow
Burnet
Trefoil
White clover
Saintfoin.

Peat.

White clover
Dog's-tail
Cock's-foot
Rib
Yorkshire white
Rye
Foxtail
Meadow fescue
Timothy.

But in proportion as a soil combines more or less of these different characteristics, its adaptation to the grasses enumerated will vary, as also by different degrees of exposure, moisture, and the manure it receives. Hence it is usual to sow a mixture of all the grass seeds that are likely to thrive in a soil, but to provide the largest proportion of those seeds, the grasses from which are the most desirable.

One of the most remarkable improvements of modern agriculture, has arisen from the attention which has been given to the different grasses: the seeds of all the valuable sorts may now be purchased separately at the seed-shops; but from the want of an accurate knowledge of them, it was formerly impossible to adapt the grass to the land with any kind of precision. We subjoin an account of the most serviceable grasses.

Meadow Grass.

The *aquatica*, or *reed meadow-grass*, grows in marshes, and on the banks of rivers, for which situations it is extremely valuable. It flowers in July and August. Horses, cows, and sheep, eat it with avidity; though it is apt to distend the bowels of cattle that eat of it largely. In the Isle of Ely it attains the height of six feet, though usually cut when four feet high. It affords, when properly dried, an excellent substitute for straw in thatching.

Smooth-stalked meadow-grass thrives best in dry situations, and retains its verdure in hot and dry seasons longer than any other plant. It springs early, affords rich pasturage to all sorts of cattle, and makes excellent hay. It greatly exhausts a soil, and the quantity of it diminishes every year in dry situations, unless well manured.

Rough-stalked meadow-grass is one of the best of British grasses. It grows on moors and moist pastures, and flowers from June to September. All kinds of cattle relish it. It requires a situation rather sheltered.

Flat-stalked, or *creeping meadow grass*, is preferred by Dr. Anderson to all the other meadow-grasses. Its leaves are fine and succulent; grow very close, and are more abundant and larger than those of the last-named grass. It is said to render the flesh of deer and sheep peculiarly tender and sweet-flavoured, and it forms a fine turf for parks.

Clover

Common clover thrives best on a stiff loam or even clayey soil. It is usually sown in spring, in the proportion of ten or fifteen pounds per acre, along with barley, oats, or wheat; but the last is the safest grain to sow with it, as in dry seasons it will sometimes overpower the others. It is also mixed with rye-grass. Cattle are apt to eat of it till they are hoven, which is best prevented by moving them constantly about the field.

White clover thrives in rich sandy and clayey loams; but it requires a dry soil, and even succeeds well on a peaty one that is well drained. When grown on light land, rolling will

much improve the crop. Where it is found wild, it indicates a good soil. It is usually sown with red clover, rye-grass, or barley, and is in blossom from May till September. Irrigation is favourable to it, though not to common clover. Sheep are not fond of it, and hogs refuse it; other cattle fatten upon it.

Red clover also indicates a good soil, and is unfit for wet situations. It will grow on a moor which is dry. It forms an excellent preparation for wheat, and makes excellent green food. It should be sown between the middle of April and the middle of May. As it requires shelter in cold weather, and without this be afforded the crop might be lost, it is frequently sown with flax, on a highly cultivated soil, as flax may generally be removed sufficiently early to allow the red clover time to grow.

Fescue Grass.

Meadow fescue grass is very hardy, thrives both in wet and dry situations, in almost every diversity of soil, and affords a sweet and nourishing food. It is rather late in flowering, but it supplies much seed, which are easily gathered. It resembles rye-grass, but is more valuable.

Sheep's fescue grass grows best in dry sandy soils, and speedily fattens cows, horses, goats, and sheep. It is good both for pasture and hay, but as it is a small plant, for the latter purpose it will scarcely be desirable to cultivate it, unless the soil be too sandy and poor for other grasses to thrive.

Saintfoin.

The *common saintfoin* has not hitherto received the attention it appears to deserve. It is very productive and durable, remaining fifteen or twenty years on light poor land, in high, chalky, and dry situations. If the soil be deficient in calcareous matter, it should be manured with chalk or calcareous marl for this grass. Horses fed with saintfoin scarcely require oats; sheep rapidly fatten upon it; and cows fed on it give a large quantity of rich milk. None of the grasses are so soon made into hay, and fit to be taken off the field after mowing.

Lucerne.

This grass is best adapted to rich, dry loams. It is raised at a considerable expense, but it is as durable as saintfoin, and the produce is more than proportionably valuable. Young recommends the land to be prepared for it by two successive crops of turnips. The seed should be sown about the latter end of March, or in April, with oats. As soon as the grain is

sown and harrowed, the lucerne should be deposited in the ground, and a light harrow passed over. It is generally ready for mowing by the latter end of May, and in six weeks afterwards will yield another crop. It has hitherto been chiefly used for soiling cattle. When lands planted with lucerne are broken up, they produce most abundant grain-crops.

Vetch, or *Tare*.

Of the *common vetch*, or *tare*, there are three kinds, but only two are much cultivated, viz. the *summer vetch*, and the *winter vetch*.

The summer vetch is raised from seed, which is usually sown at the latter end of March or in April. Eight or ten pecks of seed per acre are required for broadcast sowing; but by drilling, half that quantity will produce a better crop. It is cultivated for weaning lambs, and soiling horses and cows; its seeds are excellent for pigeons.

The winter vetch is sown in September. A small quantity of beans, or black oats, is sown to support the plants, which are generally covered with long dung to preserve them from frost. This plant is applicable to the same purposes as the former. The seeds of the two kinds resemble each other, but as the seed of each kind is only adapted to the season pointed out by its name, they should be gathered and kept distinct.

Tares are hardy, and may be successfully raised on almost every kind of soil, unless it be very wet, and the situation bleak. When ploughed into chalk land, they form an excellent manure for wheat. They require but little attention during their growth, and they will maintain more stock than any other plant. Davis, on the produce of an acre of them, maintained four horses in much better condition than upon five acres of grass; upon eight acres, he kept twelve horses and five cows, for three months, without any other food. Cattle should never roam at large over a field of tares; this grass should be cut and carried to them, or a small portion at a time, for their use, should be fenced off with hurdles.

Haymaking.

Hay should be mown when it contains the greatest quantity of nutritious juices. This will generally be at the time of its beginning to flower; but upon the whole it is better to be rather too late than too early. To obtain the greatest quantity of crop, it should be mown close to the ground;—to press

down the inequalities and stones, that this may be performed, is one of the principal reasons for rolling land.

In Middlesex, where the hay is probably better made than in any other part of the kingdom, all the grass mown on the first day, before nine o'clock in the morning, is *tedded*, that is, uniformly strewn over the field. It is turned once before twelve o'clock, and generally a second time in the afternoon. It is then raked into what are called wind-rows, and formed into small cocks before it is left for the night. On the second day, the grass mown the preceding day after nine o'clock, and what is cut on this day before that time, is tedded, and treated in the manner just described. Previously to turning the grass of the second day's work, the small cocks thrown up on the preceding day are well shaken out into straddles, or separate plats, five or six yards square. If the crop be so thin as to leave large spaces between the plats, they ought to be raked clean. The next business is, to turn the plats, and also the grass cut on the second day, which is generally done before one o'clock, in order that all the grass which is mown may be drying while the people are at dinner. In the afternoon, the straddles or plats are raked into double wind-rows, the grass into single ones, and the hay is thrown up into field-cocks of a middling size; the grass is then cocked, as on the preceding day. The work is daily carried on by a repetition of these operations, till, in favourable weather, the hay which was made into cocks on the evening of the second day, will in the afternoon of the third day be fit for leading off, and on the fourth day may be stacked. In the northern parts of Britain, hay cannot be made so expeditiously, as the heat of the sun is weaker, and the grass is not strewn so thinly over the field, from the greater uncertainty of settled weather.

When the weather is such as to prevent hay from being made sufficiently dry, the strewing of a layer of salt over a layer of hay, in the proportion of one hundred weight of salt to seven or eight tons of hay, has been found a security against the overheating of the stack; and cattle of all kinds will prefer coarse hay thus prepared, to the best of the ordinary kind.

Stacks should if possible always be erected in fine weather, and this is the more important, the more unfavourable the harvest weather has been, as the working and spreading of the hay, while stacking in the sunshine or a drying wind, will much improve its condition. The stacks should not be thatched till they have had about a week or a fortnight to settle. Round stacks require the least thatching, but oblong ones are more convenient to cut from, in order to make the hay into trusses for sale.

The after crop of hay, or rouen, is less nutritious than the first; it is not suitable for horses, but is very serviceable for sheep and neat cattle.

Ploughing.

Though a sketch of agriculture so limited as the present, will not admit the separate consideration of the various ploughs and other implements in use for different soils and operations, yet we may advert to the objects for which they are required, and with respect to implements we may offer a word or two, before we proceed further: the farmer will greatly promote his interest by an enlightened attention to their construction; for in all operations on a great scale, the accumulation of little impediments adds serious sums to an annual expenditure. He should have a general knowledge of mechanics; he should satisfy himself by experiments of the principles of draught, and should study to acquire—what he will hardly ever be so situated as to find one around to possess—a real practical knowledge of the best materials in wood and metal, and in what proportion they should be used to combine, for their several purposes, and the peculiar soil he has to work, the utmost degree of cheapness and durability; for he has equally to guard against those who deceive him from ignorance, as those who do it for profit.

The considerations to be regarded in ploughing, are, 1. the direction of the furrow; 2. the breadth of the ridges; 3. the depth to which the earth should be turned up; 4. the frequency of the operation; and 5. the season for performing it.

A proper direction of the furrow, or trench made by the path of the plough, is very subservient to the draining of land which is too wet. When the land is level and dry, the furrow should run directly north and south, as most favourable to the early maturity of the crop. On declivities, the furrows should be drawn in a direction which will give them only a small descent, as this will diminish the labour of making them, and prevent the water of heavy rains from having that rapid motion which would wash away the manure and soil.

The ridges, or space of ground inclosed between two furrows, should be narrower, the wetter and more retentive the soil; but where the soil does not require any particular precautions for its management, about eighteen feet is found to be a very convenient breadth. In order to carry off water, it is better to make the ridges narrow, than very convex or high,

as when considerably rounded, the crown of the ridge becomes much dryer than any other part, and the crop ripens unequally.

The depth to which the soil is turned up, depends upon the nature of the sub-soil; it may be varied from six to eighteen inches, but in general from six to eight or ten inches will be fully adequate to any useful purpose. Preparatory, or fallow ploughings, are made deeper than those for seed. The depth of good soil is usually very limited, and below this the plough should never go, or the manure will loose its effect; lime, marl, and other earthy manures, being very apt to sink. Experienced agriculturists deem it best not to go to the full depth of the good soil oftener than once in eighteen months or two years, and upon the whole advise shallow ploughings.

Very adhesive, stiff soils, whether clayey or loamy, cannot be ploughed with any advantage while very wet or very dry, as the labour is in both states excessive; but such soils are much improved by frequent ploughing, as it is the surest means of reducing them to that fine state which is favourable to the growth of plants. The ploughing of stiff and wet soils ought to commence early in autumn, and be repeated as often as the crops and season permit, if they have formerly been neglected; it particularly benefits them after the frost of winter has in a good degree expanded and broken up the clods, provided they be dry at the time, and not otherwise; for if they have become wet after the frost, ploughing will render them adhesive or pasty. Wet soils take less harm under a summer fallow than those of a lighter kind, which may be too much robbed of moisture by this exposure, and would be more improved by bearing a suitable green crop.

HARROWING.

The harrow is employed after the plough, 1st, to produce a more complete pulverization of the soil; 2nd, to clear away weeds; 3rd, to cover the seed with soil. The weight of the harrow, and the length, position, and form of the tine or teeth, must necessarily be such as to produce these effects in the most perfect manner; but on the direction in which it is dragged over the soil, something will depend. If after ploughing, the land is in a state so rough, that it is thought proper to harrow it, the harrow may follow the same direction as the plough; but if, after this first harrowing, weeds shall have sprung up, they may be most effectually destroyed by a harrowing which crosses the direction of the plough. To make the soil fine with the harrow, immediately after plough-

ing, promotes the early vegetation of the seeds of weeds contained in the soil, and therefore hastens the period at which they may be destroyed by a second harrowing. The teeth of harrows should be so disposed as not to fall into each others' path.

A lighter harrow than is necessary for immediately following the plough, or eradicating weeds, will suffice for covering seed. For this purpose, the harrow is first made to take the direction of the ridges, then to cross them, and lastly to observe their direction again. To cross the path of the plough in the first instance, should never be practised, where the ridges are rounded, to avoid casting part of the seed into the furrows

Hoeing.

Hoeing consists in the eradication of weeds, and the dressing of the soil while the crop is growing. It is the application of garden culture in the large way. It is sometimes performed with implements designed for manual use, and sometimes by those to which a horse is required.

A diligent system of hoeing is indispensable to good husbandry. It effects the destruction of weeds; the turning and comminution received by the soil, increases the power of the atmosphere to fertilize it, and the plants being well-earthed up, vegetate with increased luxuriance. It is most frequently required by heavy soils, and should be performed at seasons when they are only in a slight degree moist. On sandy soils it may be performed almost at any time, but in general the proper time will be in autumn and spring; thus for wheat, if the first hoeing be given when the leaf of the crop appears, the soil will then be well prepared to benefit by the winter's frost; the second may be given in spring, when the hard frost and heavy rains are chiefly over: it will replace the soil which has been washed from the plants, and render them less liable to be laid; a third hoeing, if given at all, may be very slight, and postponed till the wheat is in the ear.

Hand-hoeing is best adapted to grain-crops, which grow in rows very near each other; and horse-hoeing to those crops, such as pulse, cabbages, and turnips, which have considerable spaces between the rows. The shares of the horse-hoe must always be made to take the spaces between the rows of the plants to which it is used. Horse-hoeing is particularly subservient to the new or drill husbandry.

Broadcast and Drill Husbandry.

Three methods of sowing seeds are in general use: 1st. The seeds may be strewn by hand over the surface of the ground: this is called the *broadcast system*. 2ndly, The seeds may be dropped at equal intervals, and in regular rows, by the action of a machine: this is the *drill system*. 3rdly, Small, single holes may be made in the ground, and the seed dropped into them by hand: this is called *dibbling*.

The broadcast system of husbandry is the oldest and still the most common, although it has been proved by ample evidence to require a much larger quantity of seed, and to produce a crop which ripens later, and is inferior both in quantity and quality to the drilled. It requires considerable practice to strew the seed with a tolerable degree of evenness over the land, under the most favourable circumstances; but when the ridges are unequal, and the weather cold and benumbing, this will not be accomplished, and therefore the farmer is much at the mercy of accidents and of carelessness, which cannot be detected till it is too late. After having been thus sown, the seed is covered by passing the harrow over it; but the covering which most of the grains receive is so slight, that their germination is apt to be checked by the want of moisture; if many grains fall near together, they will not all thrive, and the grain which escapes being covered, becomes a repast for birds. Another disadvantage is, that the seeds are deposited at different depths, and therefore come to maturity at different periods.

In the system of drill husbandry, no more seed is committed to the ground than what is likely to spring up, and the management is such as is calculated to bring the whole to maturity, allowing for incidental losses which cannot be controlled. In this first place, the seed or grain is put into the ground by means of a machine, called a drill, or drill-plough, which ensures three important objects: 1. The seed is disposed in equidistant rows. 2. It is deposited at a fixed depth. 3. It is, in any given portion of each row, nearly the same in quantity. From the first-mentioned property, the assistance of horse-hoeing between the plants is acquired. From the second, arises the uniform growth of the crop; and the depth at which the seed is sown, causing it to be moister than if it were near the surface, it sooner arrives at maturity. Lastly, the distribution of the seed is such, that the plants neither injure each other by their proximity, nor is ground lost by the want of

a greater quantity of seed; while the land, by the use of horse-hoeing, is left, after the harvest, in so clean a state, as to require no fallow.

The distance between the rows in drilling, and the nearness of the seeds to each other in each row, must be varied according to the nature and state of the soil, and the space which each plant requires. Nine inches between the rows, is an average distance for grain-crops; for pease, tares, turnips, and similar green crops, eleven inches, and for beans eighteen inches. The depth may be about two inches and a half, except in very stiff clays, where two inches will be quite enough. The following table shews the difference in the quantity of seed required per acre, for producing the largest crops, according to the broadcast and drill-system, on a soil of a middling or average fertility:

Kind of seed.	Quantity required per acre, if sown broadcast.	Quantity required per acre, if sown by the drill.
Wheat	14 pecks,	8 pecks.
Barley	14	9 ..
Oats	20	13 ..
Beans	17	10 ..
Pease	15	8 ..
Tares	10	5 ..
Turnips	2 pounds,	1 pound.
Carrots	5	2 ..
Rapeseed	2	1 ..

A natural impediment to drill husbandry is, a rugged and stony state of the land, by which the action of the drill is deranged; and such land must be reluctantly consigned to the broadcast system, until reduced to a better state of cultivation.

Cooke's drill machine, improved by Dr. Darwin, is one of the best machines of this kind in use.

Dibbling.

This mode of planting has the same object in view as drilling, viz. the saving of seed, by the regularity of distance and depth in committing it to the earth.

In dibbling, after the land has been ploughed, harrowed, and also rolled if it be a very light soil, a man, having in each hand a staff about three feet long, pointed with iron, makes two holes at once, as he moves backwards, and takes care to keep the successive holes as nearly as possible in a right line,

and at regular distances. Two or more children attend him, and drop two, three, or four seeds into each hole. These seeds are afterwards buried, by passing over the land a light harrow. This plan is chiefly used for the lighter descriptions of soil, but may be practised with advantage, to render the broadcast system unnecessary, for lands which are in too rough a state for the use of the drill. Wheat, pease, beans, and turnips, are often dibbled, and acorns generally.

The expenditure of seed is so small by dibbling, that three pecks of wheat will serve for an acre; whereas drilling requires almost three times that quantity, and broadcast nearly five times: the drawback upon this advantage is, that a great number of hands are required to get through the work: but when corn is at high prices, the advantage will be in its favour, in the vicinity of towns and places where the labour of women and children can be obtained at a low rate. It admits and requires, like drilling, the practice of horse-hoeing.

Rotation of Crops.

A variety of circumstances conspire to render the alternation of different crops an indispensable part of successful husbandry. Some crops appear to draw from the soil such liberal supplies of principles which can only be slowly communicated to them again, that the soil is, with respect to such produce, exhausted, and the unintermitted succession of it would be unprofitable. Manure might renew the fertility of the soil, but it is interdicted by the expense of supplying the quantity required; a fallow would prepare it for another crop, but this introduces the expense of ploughing, while the land is unproductive. The most effectual means, therefore, of relieving a soil, and to obtain from it the maximum of produce, has been found to consist in a rotation of crops, which draw from the soil different principles, or very different proportions of the same principles. Thus white crops, viz. those of wheat, oats, &c. are extremely exhausting, but afterwards the soil will bear a good crop of beans, turnips, or tares. Probably the difference in the nourishment required by these fallow crops, is far from the whole advantage of them: the hoeing and harrowing they receive, may enable the soil to replenish itself from the atmosphere, while their shade, and the extirpation of weeds attending their culture, prevents waste.

The following rotation of crops has been proposed by an experienced agriculturist, where the turnips, pease, and

beans, are put in double rows on three feet ridges; the cabbages in single rows of three feet ridges; and the whole hoed and cleaned with the utmost care:

Clay.	*Clayey Loams.*
Turnips or cabbages	Turnips or cabbages
Oats	Oats
Beans and clover	Clover
Wheat	Wheat
Turnips or cabbages	Turnips or cabbages
Oats	Barley
Beans and vetches	Beans
Wheat.	Wheat.

Rich Loams and Sandy Loams.

Turnips and potatoes	Beans	Turnips
Barley	Barley	Barley
Clover	Pease	Clover
Wheat	Wheat.	Wheat
Beans	[This rotation may	Potatoes
Barley	be continued dur-	Barley
Pease	ing pleasure.]	Pease
Wheat.		Wheat.

Peat Earth.	*Light Land.*
Turnips	Turnips
Barley	Barley
Clover	Clover and ryegrass
Wheat	Clover and ryegrass
Potatoes	Clover and ryegrass
Barley	Pease
Pease	Wheat or rye
Wheat.	Wheat.

When the soil has a chalky substratum, and for gravels, the same course as above given for peat earth is recommended, excepting that on the former, 10 acres in every 100 should be laid with saintfoin for 8 or 10 years.

Of the Culture of esculent Plants, Hemp, and Flax, Fruit and Timber Trees.

Wheat.

Wheat is of all grain the most valuable. It is a very hardy plant, sustaining alike, without injury, the frosts of winter and the heats of summer. It delights most in a stiff, mellow, well pulverized soil, and very successfully follows beans, clover, pease, or vetches. On very light soils, it is not profitable to cultivate it.

The kinds of wheat chiefly cultivated in this country, are, the *smooth* or *polled wheat;* that with a rough or bearded ear, which is called *rivet wheat;* and that called *spring wheat,* on account of the season in which it is committed to the ground. The polled wheat is the most general, and produces the finest flour: but the rivet wheat is the hardiest, and though it will not obtain so high a price, it is better suited to wet clayey soils, or lands newly broken up. Spring wheat has not yet received much attention, but the few experiments which have been tried, are favourable to its utility. It is found to ripen as early as other wheat, where the situation is not very bleak, and is therefore extremely useful where much green food, such as turnips and tares, is raised for cattle during winter. It has a smaller grain, and is worth about one shilling per bushel less than other wheat.

Wheat seldom succeeds well after potatoes, because this root is considerably exhausting to a soil, and renders it light and porous; wheat also, after it, is particularly liable to be attacked by insects. When this succession is adopted, the land should be of a stiff quality, and a large quantity of manure should be used to the potatoes.

The proper season for sowing common wheat is towards the latter end of September, in October, or the beginning of November; the earliest period mentioned being adapted to the heaviest lands, which it is difficult to sow at all in wet weather; and the latest period, for the lightest land, which can scarcely be sown too wet. This grain, when in a healthy state, is known to be ready for reaping by the yellowness of the straw, and the plumpness and hardness of the grain: if there be any appearance of blight, it must be instantly cut, as the straw will never become yellow, but black, and the circulation of the sap ceasing, the grain will decrease. By cutting and drying it well while green, the wheat thus injured will often prove tolerably good, and the straw will be tough and fit for thatching.

The smut, which often proves fatal to wheat and other grain

crops, appears to be occasioned by a peculiar state of the seed; from the seed, therefore, various attempts have been made to remove the infection, by steeping it in saline, alkaline, or acidulous fluids; but *repeated* washings and agitation in pure water, have been found by J. Wagstaffe, of Norwich, fully as efficacious as any other preparation.

The thrashing of wheat, and all other grain crops, is most advantageously performed by machinery, to guard against the effects of idleness and other dishonesty, in the men employed. Machines may be obtained at various prices, from 40 to 100 guineas, to be turned by horses, or a small stream of water, as may be required.

Barley.

Barley is much less hardy than wheat. A rich, sandy soil, is the most favourable to it; on heavy, cold, clayey soils, it is raised with difficulty and hazard. The more nearly a soil is of the clayey character, the greater pains should be taken to open and mellow it. The common or spring barley should be sown in March; in the southern districts earlier; in the northern, later. The best preparation for this grain is formed by turnips, but any other ameliorating crop may be adopted. It should be sown when the land is dry, and if, in waiting for this, the sowing be late, the quantity of seed should be increased.

The *bear* or four-rowed barley, and the *big* or six-rowed barley, are winter barleys, and are sown in autumn, like wheat.

Barley bears a wet summer better than wheat, but it should be housed very dry, to prevent it from heating.

Oats.

This plant is hardy, and may be successfully reared upon almost every sort of soil, after green crops. Lands newly broken up from grass, afford most abundant crops of it. They may be sown in January, although the following month is a more proper season; March is not too late, but the earlier it is put into the ground, the sooner it will be ready for the sickle.

There are many varieties of oats, of which the most common and useful are, the *white*, the *black*, the *red*, or *brown*, and the *potato* oat. The white oat is chiefly cultivated in South Britain; it is the most valuable kind, and yields the whitest meal, but requires rather a dry, rich soil. The black oat is nearly of equal value, for feeding cattle, and will grow on poor, wet land. The red or brown oat ripens earlier than either the white or black, and its grain is heavy. It is hardy, and fit for stiff land. The potato oat is hardy and productive, and may be grown on almost any kind of soil.

Rye.

Of rye there are two principal kinds, the *winter* or *black* rye, and the *spring* or *white* rye. The black rye is the most valuable, and the most commonly grown.

Rye is very hardy, and will thrive on soils too light, dry, and sandy, for wheat and barley. It is therefore usually grown on such soils only, excepting where a large flock of sheep is kept; it then becomes useful to grow it for the pasturage of the ewes, as it causes their milk to flow abundantly, and thus becomes of the first consequence to the nourishment of the lambs. The two kinds of rye are sown about the same time as winter and spring wheat. When grown for grain, it should be well freed from weeds.

Buck-wheat.

Buck-wheat has many valuable properties, which entitle it to more attention than it has yet received. It will grow on almost any dry soil, but delights most in the dry and sandy; it should never be sown on wet soils. It scarcely requires any manure, exhausts the land but little, and forms a good preparation for wheat or barley. It is as valuable as barley for hogs and poultry, and a much less quantity of seed is required to be sown; a bushel per acre will serve, if it be sown broadcast, but less than two pecks, if drilled. It should be sown in the last week of May, but the time of sowing may be protracted till July with very little hazard, such being the rapidity of its vegetation, that it will be at maturity in little more than three months. As it is apt to shed its seed when ripe, it is advisable to cut it with the dew upon it. It is a very proper grain for sowing with grass seeds. It yields a white flour, but has no other resemblance to wheat.

Beans.

A clayey soil, or strong loam, rather wet, is the most favourable to beans, but they may be grown on any soil intended to bear wheat, for which a crop of them forms, in general, perhaps the very best preparation. They are to be drilled or dibbled; and are sown from January to March, the later the more northerly the district. They require manure. Bean-straw makes good fodder, when cut to chaff.

The beans usually eaten at the table, are those called Spanish and Windsor beans; the horse-bean, from which all other kinds are derived, has a higher stem than these, and requires rather a stiffer soil.

Pease.

The pea succeeds best on a dry, warm soil, rather light; the dryness is the most important circumstance, and it ought not to be deficient in the calcareous ingredient. Several varieties of it are cultivated, which ripen at different periods. The *Charlton*, or *forty-day* pea, the *golden hotspur*, and the *common white*, are called early pease, and are cultivated both in the field and in gardens; the *Marlborough gray*, the *horn gray*, and the *maple gray*, are late pease. To obtain a succession of them green for the market, they are sown upon land which has undergone an autumnal ploughing, at intervals of about a fortnight, from the beginning of January to April; but for crops to be ripened, the beginning of March is the proper sowing season. Pease do not require manure, and they ameliorate the land so much, that they are very proper either to follow or precede white grain. Gray pease are generally planted on the poorest land. Pease are often sown on land newly broken up, on which it is deemed unsafe to sow grain, on account of the worm.

Potato.

The better this root is known, the more it rises in estimation, as an article of food for man and beast. It is planted by setting the small roots entire, or by cutting the large ones in pieces, reserving one eye or bud in each; but the *rind* only will produce plants as perfect as those obtained by any other means. The varieties of the potato are numerous. Kirkpatrick states, that in Lancashire, more than twenty sorts of early potatoes are known, and more than half as many more of the later sorts: but the best precaution which can be given, in selecting them for seed, is to take those which are the largest in size, and the most agreeable to the taste. The sorts best known by name, are, the common kidney, the American kidney, the Aylesbury white, and the Altringham early white, all of which are fit for the table; the ox-noble, Surinam, Irish purple, Howard or clustered, and red potatoes, are for fodder.

Potatoes may be reared on almost any soil, but they thrive the most, and have the best taste, when grown on light gravelly and sandy soils, neither very moist nor dry. Though not palatable to man when grown on a clayey soil, they are greedily eaten by cattle. Potatoes require a liberal supply of manure, and if the soil be naturally too stiff and close for them, the culture and manure should be such as to open it as much as possible; the long litter of the farm-yard is particu-

larly proper. Potatoes should be drilled in March or April, the land having first been repeatedly ploughed and harrowed, and while they are young, they should in hoeing be well earthed up.

Potatoes are often extensively injured by the *curl*, a disease in which their leaves shrivel up, and the cause of which, unless a general effect of a weak state of the plant, is not yet discovered. The best modes of guarding against it, consist in using seed from distant districts, and in promoting the health of the root by careful culture.

Turnips.

Of the varieties of turnips, the most important sorts are, the *round red* or *purple-topped*, the *green-topped*, the *white-topped*, the *yellow*, the *black* or *red-rooted*, the *stone*, the *Dutch turnip*, and the *Swedish turnip*. All these sorts have globular roots, but there are other sorts which have a longish cylindrical root, and are called the *tap-rooted* sorts. The Swedish turnip is the most hardy, and affords excellent food for cattle; but as it is of slower growth, its seed ought to be sown earlier than that of other kinds. In very rich or heavy land, turnips are apt to be rank, but the Swedish is least affected in this way. Dryish, chalky, gravelly, sandy, and almost all soils except clays, are fit for the cultivation of turnips; but the seed from which they are raised should be changed at least every second year. The time for sowing must be regulated by the use to be made of the crop. If the crop be wanted for feeding cattle from December to February, the seed must be committed to the ground from the middle of May to the end of June; but if the food be wanted in May, the latter end of July, or early in August, will be soon enough for the seed to be sown. The seed is drilled. Munning's turnip drill, and that by Knight, are both excellent. The plants should be hoed and thinned once or twice in the course of their early growth; they should be left at last about 12 or 14 inches asunder, and kept well freed from weeds. They require the land to be enriched by manure. To deposit the seed when the ground is moist, is of so much consequence, that the drill machine is often attached to the plough, to perform the ploughing and sowing at once. Turnips leave land clearer of weeds than any other esculent crop.

Carrots.

Carrots delight in a warm, light, sandy loam, and require a deeper soil and deeper ploughing than any other plant; the soil should be at least a foot deep. If the land be not sufficiently light in itself, or thoroughly opened by the plough, the

roots will divide into branches, instead of striking downwards. They must not be manured, as it would be liable to rot them. The seed should be sown about the middle of March. The plants should be from fifteen to eighteen inches apart. Carrots form excellent food for all kinds of cattle; one acre is equal to two and a half of turnips.

Parsnips.

Parsnips are well entitled to the farmer's notice. It is the garden parsnip which is cultivated in the field. They are more hardy than the carrot, while their roots, which are similar in shape, are larger, equally nutritious, and as wholesome and agreeable both to man and beast. They may be raised on almost any deep soil, except gravels and clays. They require, like the carrot, deep ploughing, and the seed should be sown in autumn, just after it is reaped, which will generally be in September: this season of sowing is pitched upon, in order that their growth may precede the growth of weeds; but it will perfectly answer to sow them in February. The severest frost will not destroy the seed. In a rich, friable soil, they require no manure. The drills should be eighteen inches apart. Cattle prefer parsnips to potatoes, and cows fed on them in winter, give an extraordinary quantity of milk. Parsnips require careful hoeing, and should be earthed up, to make them luxuriant.

Cabbages.

Where the soil is too compact for the profitable growth of bulbous and tap-rooted plants, the farmer has an invaluable resource in cabbages, which, on stiff soils, will grow extremely well. They supply a large quantity of palatable food, and are reared with great facility. Of the various sorts of cabbage, fit for field culture, the *Scotch gray*, the *open green* or *spring kale*, and the *turnip-rooted*, are the hardiest. The ploughing for them should be rather deep, and the soil well loosened. The newest seed should be selected; the time of sowing must be regulated by the season at which the crop is required to be eaten off. By sowing them at intervals of a couple of months, from February to August, a useful succession of crops will be maintained. About half a pound of seed will produce a sufficient number of plants to stock an acre by transplantation, which is favourable to their growth. The distance between the plants, when left to attain their full growth, may be about three feet by two, more or less according to the size of the sort planted. Beans are often intermixed with cabbages, as a protection to them from the caterpillar, and a top-dressing of soot is used with the same view. Cabbage lands require manure.

Rape, or *Cole*.

This plant is reckoned by botanists a species of cabbage, but it does not form a close head. It is cultivated for the green food which it affords for sheep in winter, and for its seed, which by expression yields an oil called rapeseed oil. For green food, it may be sown in June and July, and comes in most seasonably, if the frost prevents turnips from being taken up. When planted for seed, it is sown in August: the severest frosts do it no injury. It may be planted, like the cabbage, in beds, and transplanted. The produce is by far the most abundant from heavy land. In reaping it, great care should be taken not to shed the seed; also to select fine weather for this operation, and to accomplish it with rapidity, as rain would be fatal to the success of the harvest.

Hemp. (*Cannabis sativa* of Linnæus.)

The growth of hemp cannot be attempted with any hopes of success, except on a soil naturally of the richest kind, and which can be further improved by abundance of the best manure. A deep, black, putrid, vegetable soil, and a low, warm, rather moist situation, are particularly favourable to it; the more the soil inclines to a sandy loam, the greater is the quantity of manure which will be necessary; but on the best land, it is recommended to lay from 15 to 20 three-horse cart-loads of manure per acre. About ten pecks of seed per acre are required, and sown broadcast, because from the rank growth of this plant no weeds disturb it, and no after culture is required; but to balance this advantage, it returns nothing to the farmyard. As it is pulled up along with the root, it leaves the land very clean, and is a good preparation for grain crops. English hemp is reckoned superior to foreign.

Flax. (*Linum* of Linnæus.)

Of common flax, as of hemp, the fibres which are so useful in the former for linen, and in the latter for cordage, lie between the wood and exterior coat or bark of each stalk, and are obtained by steeping and beating. Its seed is called *linseed*. It requires a soil and situation similar to barley or oats. A very rich soil causes it to be rank and coarse, and it also suffers from great wetness or drought. It is cultivated as well after grain as after green and root crops. Riga seed is most esteemed, and about two bushels are required for an acre. It is sown by drilling, at a very slight depth, and hoeing is required. From the middle of March to the middle of April is the sowing season, and by the end of July or middle of August

it is ready for pulling—an operation which should always be performed before the leaves fall off, when the stalk begins to turn yellow, unless it is to be reserved for seed. It may with great advantage be succeeded by a crop of clover, turnips, or wheat. A top-dressing of soot is used to destroy insects.

Hops.

The hop is a valuable but delicate plant; it is grown for the sake of its flowers, which form the hops of commerce. To cultivate it with success, requires extreme care, considerable experience, and a large capital. Yet perhaps of no plant is the harvest so precarious, from an unfavourable season, and the depredations of insects. The cost of cultivating it is reckoned at £80 per acre for the first year, and at £40 for subsequent years. There are several varieties of it, as the *red bind*, the *green bind*, and the *white bind*, of which the first is reckoned the most hardy, but it is the smallest.

The hop requires a rich, vegetable soil, with an under stratum of rock or clay, rather dry than otherwise, and sheltered, in some measure, from north and north-easterly winds. A chalky soil is most improper for it; and those plantations which are near the sea, are found to be soonest injured by mildew. It is propagated by nursery plants, or by cuttings. These are planted in little hillocks, usually called hills, formed by digging a hole 12 inches deep, and 18 inches in diameter, and filling it up with fine mould, mixed with manure and the original soil. In the centre of the hill is set a single plant, and round it half a dozen others. The hills are about eight or nine feet asunder. Cuttings are set in February or March; but sets, or nursery plants, in autumn. In April, if the season be favourable, the binds require tying to poles which are struck in the earth. About midsummer they are pruned, and the produce given to cattle. In September they are usually ready for pulling. Chesnut is reckoned to make the best poles, and ash the next; the poles are from 18 to 24 feet in length; three poles are sufficient for a single hill, or two poles where the plants are vigorous. The large poles are not required till the first winter after the plantation has been formed; and it is advisable not to take any produce the first year. A free circulation of air is necessary to the health of hops.

Fruit Trees.

Of the fruit-trees which come to perfection in the open air of this country, the apple is the most useful, and the only one extensively cultivated. In Worcestershire, Herefordshire, Devonshire, and some other countries, where it is grown for mak-

ing cider, it often forms one of the farmer's most important objects. Although the varieties of this fruit are numberless, and often nameless, they are all supposed to have originated from the wilding, or common crab-apple, and in raising them for the orchard or the field, crab-kernels yield the best and most hardy stocks. The apple will succeed on most soils which are not very wet. Clayey soils produce the apples from which the best keeping cider is obtained, but the valuable table kinds, such as the golden pippin, delight most in a deep, light, sandy soil.

The method of propagating the cider-fruit trees in Herefordshire, is by grafting. Very large, and even old trees, may be grafted so as to bear fine heads of other sorts; and thus they will produce a crop of fruit more quickly than by any other method. New orchards are raised by planting well-grown crab-stocks, and grafting them after the second year. In transplanting the stocks, which may be done in autumn, they should not be set deeper than they originally grew.

The apple-trees in an orchard, should not stand nearer than thirty feet. They frequently require pruning, and are often ruined by the injudicious mode of performing this operation: the tree should be left more compact than it usually is, by lopping the extremities of the branches, which should not be left bare, but reduced in number, so as not to crowd one another, rather removing a branch entirely, than leaving merely a tuft at its extremity. The apple blossom is exceedingly apt to be injured by the frost, and by insects, which feed upon the heart of it; but an insect called the American bug, which feeds upon every part of the tree, and has the appearance of a white efflorescence, has of late years produced most extensive mischief; if not soon eradicated, it inevitably destroys the tree upon which it fastens, and it is very difficult to destroy; greasy substances, particularly goose-grease, have proved the most effectual application, rubbed on wherever it is observed.

One of the easiest and best means of preserving apples through the winter, consists in putting them into barrels of dry sand.

The pear-tree is still more hardy than the apple-tree, and may with still greater ease be raised in almost any situation, not very wet. As it grows much taller than the apple-tree, it requires at least a double space of ground. Pear-trees are propagated by engrafting, and by budding upon free stocks, that is, stocks that have been raised from seed, or upon quince-stocks. The pears which are the best for making perry, are extremely harsh and unpalatable in their fresh state.

Timber Trees and Coppices.

It is a material object in planting timber trees, to suit the tree to the situation and soil, so as at once to obtain a thriving produce, without making any uncertain sacrifice to obtain it. Thus, if trees which rise to a great height, and overshadow much ground, be planted in the hedges of low, moist situations, they will hinder evaporation, and at critical periods most injuriously prevent the free circulation of air, and the full action of the sun's rays upon the land, in consequence, lessening the produce of fields incomparably more than their value will ever recompense; but when properly situated, trees are too important a source of wealth to be neglected.

The season for planting commences in October, and may be continued through the winter, while there is no frost. In transplanting trees, the north side should be marked, and each of them should have the same aspect in its new situation as before, or its growth will be checked.

Single trees, in fields or fences, will not, on an equal soil, grow so rapidly, nor, when at maturity, be equal in bulk to those in plantations. The cause of this appears to be their full exposure to the winds; and as a confirmation of this opinion, it is remarked, that the outside trees of plantations are more stunted than the central ones. This being the case, it evidences the propriety of not unnecessarily lengthening plantations; a circle has the least surface of any figure for its area, and the more nearly the ground-plan of a plantation approaches to a circle, the fewer will be the number of outside trees.

The oak is luxuriant in hilly situations, where there is a moist loam, or rich black soil. It is propagated generally from acorns, of which from four to six bushels are used upon an acre: seeds of furze are sown along with the acorns, to protect the young plants from cold winds and rabbits. Young oaks may be transplanted in their fourth or fifth year; they may be two or three times transplanted, if the tap or principal root be cut off at each removal; but the hardiest trees are those which grow where the acorn was deposited.

The beech is also raised from seed; it delights in a calcareous or chalky soil, and bears the sea air better than other trees. In exposed situations, Scotch firs are planted to shelter the beech, and afterwards cut down.

The elm is usually propagated from seed, or by suckers taken from the roots of old trees. It grows the quickest on a

light soil, but produces the closest and best wood on stiff soils. Most kinds of cattle eagerly eat its leaves, and it does not destroy the grass among which it grows.

The larch will grow in almost every kind of soil and situation, and will even flourish where most other trees can hardly live, provided its roots can penetrate to a sufficient depth: cold gravelly soils particularly favour it. It is propagated from seeds put into light earth, and is transplanted at the end of two years. It should never be omitted on estates fit for it, as it is of all the resinous trees the most valuable, and perhaps makes a greater return than any other tree. For the first three or four years, it grows slowly, but when 20 years old, its girth exceeds that of a fir-tree twice its age; and in 24 years, it is from 50 to 60 feet high. It should be felled in July. The larch is an excellent nurse to more tender trees. Its bark may be used instead of oak-bark in tanning, and forms as durable leather, while it is softer and better coloured.

The Scotch fir requires a light sandy soil, on which it flourishes, however poor; in a black soil it becomes diseased, and perishes on a chalky one. It is propagated from seed, the plants from which are transplanted at the end of four years; the tap root should be carefully preserved from injury, or the tree will remain a dwarf. It grows the most rapidly, and attains the greatest height, on the north and east sides of hills.

The birch and hazel may be grown in almost any situation; the ash, which, from the early value of its wood, should never be forgotten, suits a light, rich, calcareous soil; the poplar is most luxuriant in moist situations, such as the banks of rivers; for wet, marshy land, the willow is admirably adapted, and though the first expense of planting it is considerable, in two or three years it begins to make a return, and as the plantation increases in value every year, the produce soon becomes very important.

The kind of trees to be planted for coppice or underwood, will depend very much on the local demand; for the planter will generally find a near market the best, as the charge of carriage, for any considerable distance, on an article so bulky, proves very destructive to profits. In fourteen years, coppices are generally fit for cutting; the period, however, for cutting them must principally be determined by the use for which they are required, and must be deducted from a calculation of the difference of interest that will be received, according to the times which they are allowed to stand. The season of felling usually commences in November and is continued to the end of March, but not later, except for trees which are to be

barked, for which May is the best month. The oldest wood should be cut the latest in the season.

Of Live Stock.

Horses.

The improvements which have been recently made in agriculture, are remarkably conspicuous in the feeding of cattle: economy in the feeding of live stock has been introduced, while a superior degree of fitness in the animals for the purposes required of them, has been obtained.

When corn is given to horses, they swallow a great part of the grains entire; but as their stomach will not act upon grains, the husk of which is unbroken, the unmasticated part contributes nothing to their nourishment. No farmer should therefore be without a machine for crushing corn, by the use of which any given quantity will go at least one-fourth further than uncrushed grain. Ground grain does not answer. The crushing machine, as usually constructed, consists of a wooden frame, on the top of which are two fluted cylinders of cast-iron, about twelve inches long, five or six inches in diameter, and on their circumference, in the direction of their length, about six flutes in the inch. The fluted cylinders, by the assistance of wheel-work, are turned by one handle, and are so near together when in motion, that every grain of the corn, which falls between them from a hopper placed above, is crushed in passing down. The wooden frame is hollow, to receive the prepared grain. A fly-wheel is added to assist the working.

The practice of soiling horses, instead of turning them to grass in summer, is another very excellent means of reducing the expense of keeping them, without impairing their condition, or capability of working. In the pasture, their dung is of no value, but if plentifully littered, and daily supplied with lucern, tares, clover, saintfoin, and other nourishing grasses, the manure they supply will almost balance the expense of their food. Winter tares should be more sparingly used as the summer advances, as when they begin to rot in the ground, they are unwholesome. Turnips, potatoes, and carrots, also afford horses very nourishing food, and are much used in winter, when green food cannot be obtained. If these roots be eaten raw, a little corn should be allowed, in a busy, working season; but if boiled, corn will scarcely ever be necessary, and chaff may be mixed with them. By means of a steam-

apparatus, the boiling is easily managed to any extent. Thick and broken-winded horses, fed on carrots, will, it is said, recover, if curable. Where furze is grown, the use of it makes a valuable addition to the food of horses. Hay always goes the furthest when cut into chaff.

The horses best adapted to the general purposes of agriculture, are principally of three breeds, viz. the *Cleveland Bays*, the *Suffolk punches*, and the *Clydesdale* horses. The Cleveland bays are most common in Yorkshire, Durham, and Northumberland; they are large, active, hardy, strong, and rather elegant in their form. The Suffolk-punches which are common in the district called High Suffolk, have an inelegant form, and are not large, but they are hardy, strong, and persevering. The Clydesdale horses, which are common in the district of the Clyde, in Scotland, are of a good size, active, hardy, and being light in their form, are well suited to hilly countries.

Oxen and neat Cattle.

The question, whether it is more beneficial to keep horses or oxen, for agricultural labour, has been much contested, and is not yet decided. The objections to the horse are the expense of breeding and keeping him, his progressive declension in value, and the worthlessness of his carcase at last; but the facility with which he executes every kind of draught, the superior activity of all his motions, the greater number of hours which he can work in a day, and the less liability of his hoof to injury, which is of moment on stony soils, are advantages of great consequence, which he has over the ox: the food of the ox, however, costs very little; grass, straw, and occasionally a little hay, when hard wrought, is all that he requires; he will draw the plough on hilly land, and a tough, clayey soil, where the horse will scarcely move; and can at any time be readily fattened. Oxen which have been worked, are more prized by graziers than other oxen, as they fatten sooner, and their beef has a finer flavour. Whatever, therefore, may be hereafter the fate of the general question, we may observe, that on the king's farms, in the neighbourhood of Windsor, oxen have been found to answer so well, that not a horse is now kept.* Upon the two farms, 200 oxen are kept, including those coming on and going off; 40 are bought in every year, rising three years, and are kept as succession oxen in the park;

* *Vide* the account of the improvements in the Great Park, at Windsor, communicated by Nathaniel Kent to the Society for the Encouragement of Arts, &c. and inserted in their Transactions vol. 17.

120 are under work, and 40 every year are fatted off, rising seven years. The working oxen are divided into teams of six, and one of the number is every day rested, so that no ox works more than five days out of seven. This additional day of rest every week, is of great advantage to the animal, as he is found to do better with ordinary keep, and moderate labour, than he would do with high keep and harder labour. In short, this is the first thing to learn concerning him; for an ox will not admit of being kept in condition like a horse, artificially, by proportionate food to proportionate labour. These oxen are never allowed any corn, as it would prevent their fattening so kindly afterwards. Their food in summer is only a few vetches, by way of bait, and the run of coarse meadows, or what are called *leasows*, being rough, woody pastures. In winter, they have nothing but cut food, consisting of two-thirds hay, and one-third wheat-straw; and the quantity they eat in twenty-four hours, is about 24 pounds of hay, and 12 pounds of straw. On the days of rest, they range as they like in the straw-yards; for they are not confined to hot stables, but have open sheds, under which they eat their provender, and are generally left to their choice to go in or out: four of them generally plough an acre a day, and do other work in proportion. They are worked in collars, which are preferable to the yoke; and they are trained by having a strap put round their necks, with a cord fastened to it, to which is attached a log of wood; this they draw up and down while at pasture, for three or four days before they are harnessed.

The breeds or varieties of neat cattle, are more numerous than those of horses, because these animals yield much sooner to difference of soil, situation, and keeping; but the long-horned sort are the most common, and the breed of them is better in Leicestershire, and some other counties, than in Lancashire, which is accounted its native district. Some breeds are remarkable for their disposition to fatten quickly, others for the quantity of milk which they afford; the difference in their size is very considerable, and the quantity of bone in breeds of the same size is remarkably variable. The best general rule which can be given, with respect to stocking an estate with cattle, is to suit them to the soil, by duly considering on what soil they were bred. Thus, as an experienced writer on this subject says, "every kind of pasture is fitted to raise animals to a particular size. When beasts of a larger size are brought in than the quality of the food is calculated to support, these animals, whether cows, horses, or sheep, or any other kind, will degenerate apace, and never prove useful until they come down to that standard or size adapted to their situation, and suited to

their food. On the other hand, when a smaller breed than ordinary is brought in, they continue to increase in bulk, until they come up to the pitch which is suited to their nourishment. But there is this remarkable difference betwixt these two progressions, in respect of profits, that in the retrograde progress, when animals are brought from rich pastures, and a comfortable situation, to the reverse, they are in every instance worse than the indigenous breed; whereas, the animals which are brought from worse to better, continue to improve, until they arrive at that perfection which the change in their situation is calculated to produce."

In the form of neat cattle, short legs, a small dewlap, a thin neck, a straight back, and broad loins, a sleek skin, a small and clean head, a deep chest, a capacious udder, with large dug-veins, are the characteristics to be sought after, and to be combined in the most eminent degree.

The more completely animals are preserved from irritation, and disposed to take rest, the more speedily they come to maturity and fatten; hence the advantage of soiling in summer, and stall-feeding in winter, on account of the rapidity with which they fatten, besides the advantage of these practices for converting the whole produce of land into useful food, instead of a great part of it being trampled down or neglected by the animal, or burnt by the excess of dung falling on particular spots. In soiling and stall-feeding, the animals should be furnished with small portions of food at once; the stall should be cleaned, and supplied with fresh litter every morning. Green food is found to go at least three times as far by the practice of soiling, and, in some experiments which have been made, six times as far, as when eaten off the field. The quantity of manure produced by this means is also very great.

The value of a cow, as a milker, should be determined, not so much by the quantity of the milk, as by the quantity of cream which it affords. Animals which have a strong propensity to fatten, do not yield the same proportion of rich milk, as when this is not the case; and large animals generally consume a larger proportion of food than small and middle-sized breeds, for the quantity of milk they afford.

Sheep.

The breeds of sheep require, like those of neat cattle, to be adapted to the soil and situation where they are kept. The most common breeds are, the *new Leicester* or *Dishley breed:* these have long wool, no horns, barrel-shaped bodies, small

bones, a disposition to fatten early, and are maintained on poorer pastures than others of the same size. The *Tees-water breed* of sheep is larger than any other, and the ewes mostly bring two or three lambs in a season, but it is only adapted to such situations as those on the borders of the river Tees, where the pastures are highly fertile, inclosed, and warm. For bleak and very mountainous tracts, the *black-faced*, or *Scotch sheep*, are best suited; for though they are small, and their wool coarse, their flesh is sweet, their hardihood astonishing, and the most scanty food supplies their necessities. There are also the Lincolnshire and the Romney-marsh breed, the Dartmoor, the Exmore, the Dorsetshire, the Herefordshire, the South Down, and the Merino or Spanish breed, and many others.

The smaller the number of sheep kept together, the better they are observed to thrive, and the less their disposition to break through fences. To improve a breed, the finest ewes and rams should be selected; and the ewes should always be two years old, although in common cases they need not be more than eighteen months. The lambing is generally contrived to be in March, or early in the following month, and the greatest difficulty, attending this kind of stock, is to supply, at this season, a sufficient quantity of nourishing food; for if the growth of the lambs be checked, the mischief is incurable. The rouen, or after-grass, which is left to grow from autumn till this time, is the most extensive and valuable resource, as it is much relished, and very wholesome. Ten ewes and their lambs may be supported throughout April upon an acre of it. Turnips afford another seasonable supply, which is found to increase the quantity of the milk of the ewes; it is useful to give a little hay along with the turnips. Irrigated meadows are almost certain to supply abundance of nourishing herbage against this season of necessity.

Previous to the shearing, which usually takes place in June, the sheep are taken to the bank of a running stream, and washed. In a few days they become dry, and are ready for shearing, which has been usually performed by advancing the shears in a longitudinal direction; but the best practice is now found to be, to pass entirely round the body of the animal in successive rings. By this means, the clipping is more closely and uniformly performed, and to secure these objects is of consequence, not only to the weight of the fleece taken off, but to the rapid and early growth of the subsequent one.

Swine.

Swine consume large quantities of food which would be of no value for any other kind of live stock; and as they are exceedingly prolific, and rapid in their growth, they may, by proper management, become an important source of profit. The breeds are of various kinds, which differ much in size. Where provision of the best kind can be supplied in abundance, the large kinds may be kept; but where it is scanty or coarse, the small kinds will be most suitable. As the sow has two litters in the year, at the distance of from four to five months, care should be taken to have both in warm or temperate weather, as in April and August; winter litters are not worth rearing, from the attention required to nurse them. Clover, and all similar grass-crops, potatoes, turnips, and other root-crops, buck-wheat, pease, beans, acorns, dairy-wash, the refuse of distilleries, breweries, starch-works, offal, and refuse of all kinds, will rapidly fatten these animals. When corn is employed to prepare them for the market, it should be ground into meal, and mixed with water.

The practice of soiling swine is found highly advantageous, from the large quantity of valuable manure which it produces, and though proverbially the dirtiest of all animals, cleanliness is greatly conducive to their health and growth; warmth also is beneficial to them.

Poultry.

Poultry are more or less a part of the stock of almost every farm; but to what extent a profitable part, is a question not easily answered. They require considerable attention, and if allowed to roam at large, they damage young hedges, and eat the seeds just committed to the earth, while many of their eggs are lost.

A full-grown, well-fed hen, will supply about 200 eggs in twelve months; but 10 or a dozen are all that she can rear at a time. Smoke is said to be very congenial to these birds, because large quantities of poultry are reared in the smoky cottages of Scotland and Ireland; probably the warmth and dryness is more essential. Too high feeding is as injurious to them as the contrary. It is necessary that they should have access to grass, gravel, and clear water: if fed with boiled potatoes, they will require no corn.

Turkeys are valuable and delicate food, though they require still more care than common fowls. The finest breed of the kingdom is that of Norfolk. In that county they are fed chiefly

on buck-wheat, and the dryness of the soil is considered very favourable to them. The female has seldom more than one brood of about a dozen chickens in a season. The young are fed at first with bread steeped in milk, afterwards with boiled potatoes and barley meal. Turkeys, if plentifully supplied, are too voracious not to eat as much food as they can digest, and it is only what they digest that will contribute to fatten them; the practice of stuffing them, is therefore not only cruel, but absurd. Access to sand or gravel is necessary for them. The dead weight of a turkey may be reckoned at two-thirds of its live weight.

Ducks are more indiscriminate feeders than any other kind of poultry; acorns, caterpillars, snails, the entrails of other animals, and almost every kind of filth, contribute by turns to their repast. It answers best to keep them where there is water for their aquatic excursions, and they require sand. If turned into cabbage and turnip fields, they will do considerable service, by the extermination of insects. Their flesh is the most wholesome when they receive much grain, boiled potatoes, acorns, and other vegetable food; when fattened on animal food, their flesh resembles that of the wild-duck. The female need never be allowed more than ten or a dozen eggs for one brood, and food and water should be provided to prevent her leaving them.

The goose is probably the most valuable of all domesticated birds. The most abundant flocks of them are kept in the fens of Lincolnshire; they are there plucked five times a year for their feathers, and twice, or at most three times, for their quills. The goslings are not plucked till about fourteen weeks old, and only for feathers at that age. When properly plucked, and well fed, they are more healthy than if their feathers were allowed to drop by moulting. Geese seldom hatch more than one brood of eight to twelve in a season. A nest of straw should be provided for them, contrived so as to prevent the eggs from rolling out, as they turn them every day. They sit for about a month, and during that time, require considerable attention in supplying them with food, water, and sand. In fattening them, they should have exercise, or their flesh will be unwholesome, and it is found the best means to hasten the period of their being fit for market, to give them variety of food, such as boiled potatoes, chopped carrots, and the herb duck's-meat, mingled with bran, with the run of grass and stubble-fields. Under this treatment, they will sooner be ready, than if cooped up in small, dark places, a plan which is sometimes tried with the same view.

Of the Dairy.

Cows which afford the largest quantity of milk, are not always the most suitable for the supply of the dairy, but those of which the milk affords the largest quantity of cream. The Alderney cows have long been esteemed for the richness of their milk; but as they are delicate, and only suitable for rich, warm pastures, they are not commonly kept. The farmer, therefore, who has a considerable proportion of suitable pasture, will find it his interest not so much to depend on any particular breed as upon his own management. He should purchase, at first, the best of the sort which he knows will suit the soil and situation of his land, and reserve the offspring of those which he finds to be peculiarly productive. But after a valuable breed of milk-cows is obtained, much will depend upon the conduct of the milkers; none but those who can be depended upon, should be employed; an artful mildness of management, with a soft hand, and gentle touch, will render the operation of milking agreeable to the cow, the milk will freely run to the last drop, and it will not only be the surest means of improving the quantity drawn at any one time, but of securing its continuance; while if, either from accident or want of skill, a part of the milk be constantly left in the udder, the cow will eventually be rendered dry. It should also be observed, that the milk first drawn is the poorest, and that it continues to improve to the last drop the udder contains. Of the milk drawn at different times of the day, that of the evening is the richest. It is usual only to milk cows twice a day; but in summer, when they have abundance of succulent food, it is advantageous to milk them three times. A strong predilection is entertained in favour of old pastures, for cows; clover, vetches, lucern, and other nourishing green food, should only be given them on the plan of soiling, as they would trample down in the field twice as much as they would eat. In winter, it is too expensive to feed them with hay, but cabbages ought to be in readiness for them, and may be mixed with straw; the heads only should be given them, the loose decayed leaves being taken off for lean stock.

The situation of a dairy should be shady, though not close, as the purity of the air is of great consequence. Its windows, or lattices, should never front the south, the south-east, or south-west. Every utensil should be kept scrupulously fresh, neat, and clean; the vicinity of a brook, or a plentiful supply of pure water from some quarter, is indispensable. The utensils

should be of wood, and the trays, or those vessels in which the milk is set to cream, should not, at most, be more than four inches deep, but their capacity may be such as to contain a gallon, or a gallon and a half. The milk must be passed through a hair sieve, before it is put into them. At a temperature of fifty-five degrees, the cream is observed to be thrown up sooner, and more abundantly, than at any temperature several degrees higher or lower. The length of time which milk is allowed to stand, is from eight to twelve hours, according to the degree in which the milk is to be spent, or the purpose for which the blue milk is wanted. The cream for churning is taken off by skimming it with a sharp-edged, shallow dish; it is then put into a barrel, until a sufficient quantity be collected for churning. This barrel should have a small cock close to the bottom of it, by which any thin serous part of the milk, which might separate from the cream before the time of churning, may be drawn off, and prevented from tainting the cream. The cream should not be churned until it has acquired a very slight degree of acidity, which generally happens in two or three, or at most four days. If the cream be churned in less than two days, though it may be well-tasted, it will not keep so long as the other. When the cows feed chiefly on the rich grass of summer, the butter has a fine, yellow colour; but winter butter is generally coloured by the use of annotta. In summer, the churn is cooled by filling it with cold water, in winter it should be warmed by hot water, previous to churning. The agitation of the milk in the churn should be uniform, and not by fits and starts. When the butter is separated, it should be taken out, and well kneaded with pure water, till all the milk is pressed from it; after the milk is pressed out, a little salt is added, and the butter is then made up for consumption.

The method of making cheese is considerably varied in different districts, as to the age of the milk before it is used, the quantity of cream it contains, and the operations gone through; but as Cheshire cheese is deservedly famous for its excellence, and is perhaps fitter for general use than any other cheese, we shall give the method pursued in making it: the evening's milk is not touched till the following morning, when the cream is taken off, and put to warm in a brass pan, heated with boiling water: one-third part of that milk is heated in a similar manner. The cows being milked early in the morning, the new milk, and that of the preceding night, thus prepared, are poured into a large tub, together with the cream. A piece of rennet, kept in lukewarm water since the preceding evening, is put into the tub, in order to coagulate the milk; with which,

if the cheese is intended to be coloured, a small quantity of annotta (or of an infusion of marigolds or carrots) is rubbed fine and mixed; the whole is stirred together, and, being covered up warm, allowed to stand about half an hour, or till it is coagulated; when it is first turned over with a bowl, to separate the whey from the curds, and broken soon after into very small pieces. The whey being separated by standing some time, is taken from the curd, which sinks to the bottom, and is then collected into a part of the tub, provided with a slip or loose board, to cross the diameter of the bottom, for the sole purpose of effecting this separation; on which a board is placed, weighing from 60 to 120 pounds, in order to press out the whey. As soon as it acquires a greater degree of solidity, it is cut into slices, and turned over several times to extract all the whey, and again pressed with weights: these operations may consume about an hour and a half. It is then taken from the tub, and broken very small by the hand, salted, and put into a cheese vat, the depth of which is enlarged by a tin hoop fitted to the top. The side is then strongly pressed, both by hand, and with a board at the top, well weighted; and wooden skewers are placed round the cheese, at the centre, which are frequently drawn out. It is then shifted out of the vat, a cloth being previously put on the top of it, and reversed on the cloth into another vat, or again into the same, if well scalded, before the cheese be returned to it. The top, or upper part, is next broken by the hand, down to the middle, salted, pressed, weighted, and skewered, as before, till all the whey is extracted. This being done, the cheese is again reversed into another vat, likewise warmed, with a cloth under it, and a tin hoop, or binder, put round the upper edge of the cheese, and within the sides of the vat; the former being previously inclosed in a cloth, and its edges put within the vessel. These various operations are performed from about seven o'clock in the morning till one at noon. The pressing of the cheese requires about eight hours more, as it must be twice turned in the vat, round which thin wire skewers are passed, and shifted occasionally. The next morning it ought to be turned and pressed again, as likewise at night, and on the succeeding day; about the middle of which it is removed to the salting room, where the outside is salted, and a cloth binder tied round it. After this process, the cheese is turned twice daily, for six or seven days; then left two or three weeks to dry, during which time it is once turned, and cleaned every day; and at length deposited in the common cheese-room, on a boarded floor, covered with straw, where it is turned daily, until it acquire sufficient hardness. The room should be of

a moderate warmth, but no wind, or draught of air, must be permitted to enter, as this generally cracks the cheese. The outside or rind of the cheese, is sometimes rubbed with butter, or oil, in order to give it a coat.

GARDENING

Gardening is a branch of agriculture, which combines ornament with utility, and employs the utmost refinement of culture, to maintain and improve the excellence of vegetable products.

Gardens are usually considered as of three classes: 1. The flower-garden. 2. The fruit-garden. 3. The kitchen-garden. The green-house, hot-house, and nursery, are repositories for productions which belong to all these classes.

Of the Situation, Soil, and Plan of a Garden.

As a garden usually takes up but a small portion of ground, and as the object of it is often not so much for the profit, as the recreation and rational enjoyment which it may afford to the proprietor, it will always be desirable to fix it in the pleasantest situation of which the selection is admissible. The merit occasioned by the difference in prospect, is easily brought to the decision of taste; but it should be remembered that mountain scenery, particularly where water is included, will please the longest. A site is to be preferred, which is neither very elevated nor very low, and which forms a gentle declivity, screened, if possible, from north and north-easterly winds. Of the two, a situation is better when too low than when too high, on account of its greater warmth, unless the vicinity contains much stagnant water or marshy ground. A plentiful supply of water is of great consequence, and running water is better than any other; pond-water will answer equally well for water-

ing plants, but will not be so wholesome in a garden, if entirely stagnant; water drawn fresh from a spring, is too cold for watering plants, and if no other can be had, it should be exposed for some time to the atmosphere, before it is used.

Unless the soil of a garden be good, and sufficiently deep for the largest plants it is designed to maintain, the subsequent labour it will require will be immense, without being successful; its productions will consequently exhibit symptoms of disease, which no attention can eradicate. A mellow loam, which* is friable when tolerably dry, and neither clammy nor wholly unadhesive when wet, may be fully approved, as moderate labour and expense will fit it for any purpose, if it be sufficiently deep. Its depth should never be less than two feet where trees and shrubs are required; even three feet is rather shallow; and for a really fine garden, four feet of good soil may be considered necessary. If it do not already exist, the expense of the garden will in the end prove the least possible, if it be artificially increased. It is advisable to make the soil uniformly deep in every part, as well where the gravelled walks are to be made, as for the borders.

The flower-garden is generally laid out with the nicest care, and in the choicest situation; the fruit and kitchen-gardens, are generally more concealed. A shrubbery is a frequent appendage to a flower-garden, but more frequently, shrubs are intermixed with the flowers.

Miller recommends the following rules to be observed in the disposition of a large garden: There ought always to be a descent of at least three steps from the house to the garden; this will render the house more dry and wholesome, and the prospect on entering the garden more extensive. The first thing that ought to present itself to view, should be an open lawn of grass; which ought to be considerably broader than the front of the building; and if the depth be one half more than the width, it will have a better effect: if on the sides of the lawn there are trees planted irregularly, by way of open groves, the regularity of the lawn will be broken, and the whole rendered more like nature. For the convenience of walking in damp weather, the whole should be surrounded with a gravel walk, on the outside of which should be borders, three or four feet wide, for flowers; and from the back of these the prospect will be agreeably terminated by a slope of evergreen shrubs; which, however, should never be suffered to curtail any agreeable prospect. The walks should lead by gentle windings through the different plantations, where shade and seclusion may be enjoyed at pleasure. Running water, where it can be introduced, has a much more

agreeable effect than stagnant ponds. The several parts of the garden should be diversified; but wherever the eye takes in the whole at once, the two sides should be similar. Everywhere, the greatest art is required to avoid the appearance of art; nothing is more offensive to the eye of taste, than trees and shrubs cut to symmetrical figures. In the kitchen-garden, which is often conjoined with the fruit-garden, the borders should be about eight or ten feet broad; the borders exposed to the south, are fittest for early plants, and those exposed to the north for late ones, taking care not to plant any deep-rooting plants, especially beans and pease, very near the fruit-trees. The division of the ground must be determined by its size and shape: care should be taken not to have very small divisions, as they will require an unnecessary number of walks, and in the areas inclosed by treillages, plants will not thrive for want of a free exposure. A walk six feet broad will be sufficient for a garden of moderate size, but in a large one ten feet may be allowed; on each side of the walk, should be a border of three or four feet, between it and the espaliers. These borders are suitable for salads, and other plants, which neither take deep root nor continue long, and the sort should be varied each year.

A constant attention to digging and weeding, is indispensable to the success of a garden; as also the use of abundance of manure, for the properties of the different kinds of which, we refer to Agriculture; and shall now proceed to treat of the principal operations required in this branch of culture.

Of Planting.

The most proper seasons for planting in each year, are spring and autumn. The roots of all plants that are taken up, should be preserved entire, and not thinned or lopped, unless when diseased. As planting is usually performed in rows, care should be taken that the direction of the rows be north and south: the ground and the plants will then receive the greatest portion of sunshine, and plants will be more thriving than any other position at similar distances could render them.

The modes of planting in ordinary use, are the following:

1. *Hole planting.* This mode of planting is generally employed for trees or shrubs that have attained a good size. It consists in digging holes sufficiently large to admit the whole

of their roots in their natural position, or in the same position and at the same depth which they had previous to their removal. The earth at the bottom of the hole should be well loosened; the roots should be covered with the finest part of the soil, and none of the soil should be returned till it has been broken up and pulverized. If the plant be of the tender kind, the surface of the ground after planting it should be covered with long dung or turfs, to prevent its being injured by cold weather before it has properly taken hold of the soil.

2. *Trench planting.* In digging a trench for planting box edgings, asparagus, nursery plants, &c. a line is generally used as a guide; the depth and width of the trench must be proportioned to the roots it has to admit, and that side of the trench next the line is made perpendicular or nearly so; the plants are set against the upright side, and the earth being returned, the plants are fixed by treading it down.

3. *Trenching-in planting.* This method is adopted on light soils, where the plants are to have considerable spaces between them, and therefore a continued trench is not requisite. It is performed by two persons; a line being set up, or a mark made as a guide, one person turns out a sufficient quantity of soil to admit one plant, which the other person immediately puts into the hole, and the digger proceeding to make another hole, throws the soil he takes up into the hole last made. When the row is completed, the earth is trodden down as in the last mode of planting.

4. *Slit planting.* This is an expeditious mode of planting, and much used where large quantities of suckers and nursery plants are to be planted. In performing it, one person, having a line set up or marked, forms a crevice in the direction of the mark, he then draws his spade out, and forms another, by crossing the former in the middle; a boy following him, puts the sucker in at the crossing place, and finishes the operation by pressing the earth together with his foot.

5. *Drill planting.* The drills or trenches are drawn by a hoe, at the distance and depth the seed requires; the seed is dropped in, and generally covered by manual labour. Bulbous roots, and large seeds, such as walnuts and beans, are frequently planted in this manner.

6. *Bedding-in planting.* In this mode of planting, the soil having been first prepared by digging and pulverizing it thoroughly, is formed into beds three or four feet wide, with alleys between them. The earth is then raked off the surface of each bed into the alleys, and the planting being performed, it is again spread over the surface. The depth to which the soil is drawn off, must be determined by what the

seed or roots to be planted require. Bulbous roots, and large seeds, are frequently thus planted.

7. *Furrow planting* consists in the use of the plough and the harrow, and is only employed when large tracts of ground are employed for one kind of produce:—see Agriculture.

8. *Dibbling.* The principal difference between the dibbling of the gardener and that of the agriculturist, is, that the former does not close the earth by the subsequent use of the harrow, but uses his dibble, or setting-stick, to press it together and fix the plants as he proceeds. Herbaceous, shrubby, and fibrous-rooted plants, are very commonly set in this manner, as well as a great number of seeds.

9. *Trowel planting.* This is easily and expeditiously performed with a garden trowel, which serves both to take up the plant, and to make the hole for its reception. A quantity of earth is usually taken up along with the plant, and a little water is used to render it less liable to droop.

10. *Planting with balls of earth about the roots.* This practice consists in the removal of a plant or tree with as much as possible of the soil containing its roots. It is employed for all tender plants, and for the most hardy when they are transplanted at a season improper for the operation, as in summer.

11. *Planting in pots.* Garden pots should be very little larger than what the plants require at the time they are put into them, and should be changed as the plants increase in size. They should have the hole at the bottom covered by a potsherd, or oyster-shell, and when the plants are first set in them, which is generally done with more or less earth about them, the whole of the vacant space, while the plants are held upright, should be filled up with fine mould, and a watering immediately given.

In removing a plant from a small pot to a larger, the whole of the earth is generally taken up entire, and placed in the large pot, upon a bed of earth laid at the bottom of that pot, and which is enough to raise the surface of the old mould very nearly to the level it is to retain. The vacant space round the sides must then be filled up with fine mould; the plant will by this means scarcely receive the slightest interruption in its growth, and the fresh earth will in a short time cause it to be more luxuriant.

If a plant appear to be diseased before it is transplanted, the whole of the earth should be shaken from its roots, which should be examined, and any part found to be unsound should be cut off; and as there has probably been some fault in the earth, it will be proper to use none but fresh.

The mould of potted plants should be occasionally stirred

up to the depth of an inch or two, and should be watered sufficiently often to prevent its getting dry.

Of Engrafting.

Engrafting, or grafting, is the art of making a cion of one tree, draw nourishment from another tree, until in the end, the wood and bark of the tree and cion unite at the juncture, and they form but one tree. The cion or graft thus connected with another stock, bears fruit of the same kind and quality as the tree from which it was taken, whether the stock which nourishes it bears the same fruit or not. Thus a graft of the finest apple-tree will produce fruit of the finest flavour, though grafted upon a crab-stock; and in general plants are grafted upon hardy wild stocks of the same genus; for if the trees were of a different character, the operation would not succeed. Grafting affords generally the readiest means, and often the only means, of multiplying the most delicious fruits, which would degenerate if the attempt were made to propagate them from seed, or the stock of the improved variety would be too delicate to bear from the severity of the seasons. The grafts or cions should be of the last summer's growth, from the outside branches; firm, well ripened, and healthy. The graft is always the middle part of each shoot, cut to five or six inches in length, or so as to have four or five good eyes, or buds, but should be preserved at full length, till grafting time. When the cion and stock are applied to each other, they are tied with bass, and then covered with a thick coating of clay, called grafting clay, which is prepared by incorporating common clay, or stiff loam, with one-fourth of fresh horse-dung, free from litter, and a small portion of cut hay and water. The clay is allowed to remain until the union of the stock and graft is complete, which will generally be in a couple of months. Grafting is variously distinguished, according to differences in the mode of conducting it, but the most usual kinds are the following:

1. *Whip grafting* or *tongue-grafting*. This is one of the most successful and common modes of grafting. It is performed in nurseries, upon stocks of an inch or under in diameter. The stock and graft should be of the same size or very nearly so; and the sloping surfaces applied to each other in the manner of splicing a fishing rod, should be at least an inch long. As soon as applied together, they should be tied with bass, and covered with clay.

2. *Cleft grafting*, or *slit grafting*, as gardeners differently term it, is performed upon stocks from one to two inches in diameter, and requires a cleft or slit to be made in the stock for the reception of the graft, because the stock is much larger than the graft. The head of the stock being carefully cut off in a sloping direction, a perpendicular cleft or slit is to be made about two inches deep, with a knife or chisel, towards the back of the slope, into which a wedge is to be driven, in order to keep it open for the admission of the cion; the latter must now be cut in the form of a wedge, so as to fit the incision in the stock. As soon as it is prepared, it should be placed in the cleft, in such a manner that the inner bark of both the stock and the cion may meet exactly together. It is then to be tied as in the former mode of grafting. This and the last methods of grafting are usually performed in February or March.

3. *Inarching*, or *grafting by approach*, is a plan adopted when the stock and the tree from which the cion is to be taken, are so near that they may be easily joined together. It is usually practised in April or May, for oranges, myrtles, jasmines, &c. which, in the ordinary modes of grafting, do not perfectly succeed. In this process, the stock and cion, at the part where they are to be joined, are each to have their rind and wood pared away on one side to the length of three inches; a slit upwards is then made in the graft to form a kind of tongue, and a slit downward is made in the stock to admit it, that when joined together they may be less liable to slip out of their proper position; they have besides the usual security of a bandage of bass, and a covering of clay. But as the junction thus formed, may easily be strained by the motion communicated either by accident or wind to either tree, it is usual to erect a stake of sufficient strength, to which both the stock and graft are tied. In about four months, the graft may be separated from the parent-tree, by sloping it off close to the stock, and covering the bare part with fresh clay.

4. *Inoculation*, or *budding*, which is considered superior to any other mode of engrafting, especially for nectarines, peaches, and other stone fruits. In this operation, the bud of one tree is let into the branch of another, to which it unites, and putting forth branches, these branches bear fruit of the same kind and quality as the tree from which the bud was taken. To perform it, a horizontal incision is to be made across the bark of the stock, from the middle of which, a perpendicular slit should be drawn, about two inches in length. The buds are cut off from the shoots about an inch or more long, and the woody part being separated, they are inserted into the side of

the stock between the rind and wood. The bud is usually inserted on the north side of the stock. A tying of bass is necessary to secure the bud in its place, and a covering of clay as usual over the wounded part. Budding is performed in July, August, and September, and cloudy or wet weather is the most proper, as in hot weather, the transpiration of the shoot deprives the bud too much of moisture. In the course of a month or five weeks, the stock may be cut off in a sloping direction, about three inches above the bud; and in the course of the following year, it may be cut immediately above the bud. Standard trees should be budded five or six feet from the ground, but dwarf and espalier trees must be budded lower in proportion as the branches are wanted near the ground.

The best and most durable fruit-trees are engrafted upon stocks which have attained a considerable height and maturity, as from four to six feet. Hence a practice called *extreme branch grafting*, has been remarkably successful, with regard to apple-trees. Trees of this fruit, which in the ordinary judgment of them, were only fit to be cut down to a stump, after being thinned and cropped, have had a large number of grafts affixed upon them, and have thus, in the space of two or three years, again become fruitful trees.

Grafts which are intended to bear fruit as early as possible, should always be taken from fruit-bearing branches.

We may here notice the Chinese mode of propagating trees, by *abscission*, which produces an effect equivalent to engrafting, except where a stock more hardy than the graft is required. It consists in applying a ball of earth, by means of a bandage, round that part of a tree at which a branch is to be separated for forming another tree. Above this lump of earth is placed a cocoa-nut shell, or any convenient vessel, containing water, and which allows the water to ooze slowly from it to keep the ball of earth constantly moist. The branch thus situated strikes root into the moistened earth, and upon being separated below it, is immediately fit for committing to the earth.

Of Pruning and Training.

To prevent the sap of fruit-trees from being wasted, in the formation of useless wood, pruning is annually required at least once, and often twice. Dwarf and espalier trees require it the most frequently. It is generally performed in spring or winter. A sharp bill or knife should be employed, as laceration would prevent the wounds from healing. Useless buds may be rubbed or pinched off, as soon as they appear, because new buds will shoot forth with increased vigour, and shoots may be obtained to supply the vacancies of the wall. All decayed branches must be entirely removed, as they have a tendency to poison the tree; and it is also proper to remove all the shoots which spring from the trunk, and branches near the trunk. It is also necessary, in wall fruit-trees, to preserve only such branches as can be conveniently spread out.

Some fruit-trees, but especially the vine, are apt to bleed excessively when they are pruned or wounded, and it has been thought that this bleeding could not be stopped. Knight states, that he has found the following means to answer: if to four parts of scraped cheese, be added one of calcined oyster-shells, or other pure calcareous earth, and this composition be pressed strongly into the pores of the wood, the sap will instantly cease to flow: the largest branch may, of course, be taken off at any season, with safety.

Pruning cannot be properly executed without a knowledge of the nature of the tree, in order to prevent the removal of too much fruit-bearing wood: thus the fruit of the vine is borne by shoots of the same year's growth, springing from wood of the last year's growth; a supply of the best shoots must therefore be annually trained in; and these must in winter be reduced to a few eyes or buds, to force out shoots from their lower parts only: figs bear on wood a year old, of which a sufficiency must therefore be annually reserved; and these shoots must not be shortened, as it is chiefly their extremities which bear fruit: peaches, apricots, and nectarines, also produce their fruit on wood of the former year's growth; while apple, pear, plum, and cherry-trees, bear on the spurs of wood from two to twenty years old, or more.

The summer pruning of trees is the most important, and it it is advisable to perform it early, as in May or June, carefully preserving the finest shoots, and those which can be trained in the most regular manner. Winter pruning is performed from

November till March, and for such trees as require a supply of young wood, the nailing of the branches must be loosened, to admit of the alterations required in the training. Every branch should be left terminated with a new shoot, as a leader.

Knight observes, that fruit-trees, raised from seed, should neither be pruned, transplanted, nor over stimulated by a rich soil, until they have borne fruit.

Fruit-walls should have a south aspect; but the manner in which the branches should be trained is not so generally agreed upon. Knight has successfully adopted a method of training, in which a greater surface of leaf is exposed to the light, than in any of the ordinary modes, and which caused the growth of peach-trees to be such, that at two years old they were fifteen feet wide. Beginning with plants a year old, he headed them down early in spring, and trained only two shoots from each stem, in opposite directions, and nearly horizontal, for they only rose at an elevation of five degrees; when he observed any difference in the vigour of the shoots, he depressed the strongest, or gave a greater elevation to the weakest, by which the uniformity of their growth was maintained, and in a summer they attained the length of four feet. The lateral shoots were pinched off at the first or second leaf, and were in the succeeding winter wholly destroyed. In the subsequent progress of this mode of training, the large space which would be inclosed by a semi-circle resting upon the extremities of these nearly horizontal shoots, is gradually filled up by other shoots, which proceed divergently from them, until these new shoots attain an inclination of about thirty degrees, when on the side next the centre of the tree, shoots nearly horizontal are trained from them. This mode of training has a neat appearance, besides being conducive to the health of the tree.

Of the Greenhouse, the Hothouse, and Hotbeds.

The greenhouse, or conservatory, and the hothouse, or forcing-house, are buildings for the reception of exotic vegetables, which would not thrive, or come to maturity, if constantly exposed to the open air in this climate. They have, therefore, a similar object; but the hothouse, being chiefly appropriated to the ripening of the fruits of the hottest climates, requires a much greater assistance from artificial heat. The plants which can only be reared with success in a hothouse, are often called *stove-plants*.

Greenhouses are often glazed only on that side which faces the south; the roof is slated, and the remaining sides are of brick or stone: sometimes the roof is in part glazed: but as buildings of a heavy appearance have an unpleasant effect in the midst of a garden, they are frequently glazed on three sides, and over the whole roof. They then have all the appearance of a hothouse, from which they differ chiefly in requiring but little assistance from a fire, unless in uncommonly severe weather. They are intended for the occasional shelter of plants in pots, and which would perish if exposed to the open air during inclement weather, or when the nights are cold. Greenhouse plants are exposed to the open air, for a longer or shorter portion of the fine weather in summer, according to their hardiness; but when they are brought out, they should be gradually inured to the change, by placing them at first in the warmest situations; and when they are in the greenhouse, they should have fresh air in all favourable weather.

The aspect of a hothouse should, like that of a greenhouse, be such that it will receive the full effect of the sun's rays, and for this purpose it should front the south south-west. An oblong, or right-angled parallelogram, is the most convenient form, both for the construction of the flues and the distribution of the plants; but they are sometimes made in a circular form, for the gratification of fancy, or to suit particular situations. Their height must be accommodated to the growth of the plants intended to be reared, and their dimensions to the number of plants required, keeping in view a handsome proportion to the height.

In the inclination which should be given to the glazed roof of a hothouse, a very considerable diversity of opinion and practice prevails. It is well known to opticians, that the rays of the sun are transmitted through glass in greater abundance the more nearly they fall to the perpendicular direction upon it. If therefore the inclination of the glazed roof of a hothouse be such, that the rays enter perpendicularly at a season of the year when their influence is most required, the position will be the best possible; but one question will still remain to be determined, viz. when is the light and heat most essential? It has been contended, that they are most required in spring; but if it be recollected of how much more consequence a fine autumn is than a fine spring to the excellence and maturity of fruits, a doubt will scarcely remain of the accuracy of T. A. Knight's opinion, that the maximum of solar heat and light is of most consequence during the period when fruit is ripening. This distinguished horticulturist, therefore, whose acute and philosophical investigations of the economy of vegetables,

justly entitle him to rank as one of the first authorities on this subject, recommends for a vinery, that the roof should have an inclination of 34 degrees to the horizon. When this angle is adopted, the sun is vertical to its plane at the beginning of June, and again early in July, and at midsummer it is only six degrees above the point at which it is vertical. A roof inclined in this degree, admits more light than any other, between the 20th of April and 20th of August, which includes the period in which the vine blossoms and ripens its fruit, and forms the buds and blossoms of the succeeding season. A vinery which he constructed with a roof thus situated, and which fully answered his expectations, was 40 feet long, and nearly 15 feet broad: the back wall of brickwork was about 10 feet high, and the roof extended from it to the low wall of about 2 feet in height on the opposite side. It was heated by a single fire-place, the flue went entirely round without touching the walls, and in the front, a space of about two feet was left between the flue and the wall, in the middle of which space the vines, which were trained to the roof about eleven inches from the glass, were planted. Both the wall and the flue were placed on arches, by which means the vines were enabled to extend their roots in every direction, whilst in spring their growth was excited by the warmth their roots and stem received from the flue. Air was generally admitted at the ends only, where all the sashes were made to slide, to afford a free passage of air through the house when necessary, to prevent the grapes from becoming mouldy in damp seasons. About four feet of the upper end of every third light of the roof was made to lift up, this part having hinges for the purpose at the top of the back wall. By this means, when it is necessary to give air, in hot and calm weather, no additional shade is thrown on the plants as when the lights slide down. The inventor concludes that side lights for hothouses, may in all cases be dispensed with, a proper inclination of the roof admitting the solar light so much more beneficially; and that the saving will be considerable in the first construction of the hothouse, and afterwards in fuel.

The inclination of the roof above recommended for a vinery, the inventor thinks may be made to answer for pines, by sinking the front wall below the level of the floor, and making a small change in the form of the bark-bed. For peaches and nectarines he recommends a roof inclined six degrees lower than that for the vinery, because the lights, (which should be of the usual sliding construction,) will always be drawn down at or before midsummer, a long exposure to the direct rays of the sun being as indispensable to the perfection of their fruits,

as shelter from rain, dews, and cold. In a house of this description, fifty feet long, a single fire will be sufficient, by carrying the flue entirely round it. The whole of the lights should slide, in lengths of six or seven feet, two of which will be sufficient for the breadth of any house; the greater part of the lower slides should pass over the front wall, and when the fruit in the front is gathered, the chief opportunity will be afforded, by bringing down the upper slides, to perfect the fruit at the back. The walls must stand on arches like those of the vinery.

From the variable degrees of light, heat, and exposure required by different plants, it may be inferred that when a single hothouse is used as a miscellaneous depository of fruits and flowers, from various climates, they will not all be maintained in full vigour, and very few improved to the utmost; but still, by careful attention to a hothouse of this description, though perhaps not more than 20 or 30 feet long, by 10 or 12 in breadth, where profit and fame are not looked for, the admirer of nature's productions will have considerable scope for his gratification. The most potent enemies he will have to contend with, are mildew and insects. To prevent mildew, Knight has found nothing so requisite, as a sufficient quantity of moisture beneath the soil. To destroy insects, the production of which cannot be removed by hand, or prevented by attention to the due admission of fresh air, cleanliness, gentle waterings, good soil, the just proportion of artificial heat, peeling off loose bark in winter, and washing the plants with soap and water.—Mac Phail recommends, as superior to any means he has hitherto tried, the raising of the temperature of the place to a degree at which the insects cannot live. He found that the pine-apple-plant can sustain immersion in water of the heat of 140 degrees for an hour without injury. From his subsequent experiments it appeared, that a temperature rather lower could be sustained for a considerable time. He found that when the temperature of the hothouse was raised to 120 degrees, and water of the same temperature was plentifully used, his plants grew vigorously, and were always cleared of insects in a shorter or longer time. Before he performed this operation, he sprinkled them with sulphur, but he is uncertain whether he derived any advantage from that dressing.

To examine temperatures exactly, a thermometer should always be suspended in a hothouse or greenhouse; and this instrument may be obtained, with the temperatures most favourable to a great number of plants marked on it.

The bins, or beds, in which the pots containing pine-apples,

and other plants, are buried, are generally filled with bark, obtained from tanners. This substance is more cleanly, and at the same time is fitter for the purpose than any other, from its affording, by its fermentation, the mildest, most uniform, and longest continued heat. When the heat of the bark has subsided, it should be replaced by fresh: if the bark-bins are next to the back wall of the hothouse, this can be conveniently done by raking it out through apertures left in that wall for the purpose, and kept closed at other times.

As it is one principal use of a hothouse to avoid sudden inequalities of temperature, an outside door should never open directly into it; there should always be a small antichamber, or porch, and the outer door should be closed before the inner is opened.

Hotbeds, called also *forcing frames*, are contrivances for bringing cucumbers and other plants to early maturity: they answer, on a small scale, the same purpose as a hothouse, without requiring any very extraordinary trouble or expense, and many seeds germinate in them, which would remain for years in ordinary ground, without any symptoms of growth. The heat of hotbeds is derived from a deep bed of horse-dung, or tanners' bark, which is covered with fine mould; and a frame being put over this, the fermentation soon commences. If horse-dung be employed, the first violence of the heat should subside before any seeds are sown; but if bark be used, the sowing may commence at any time. The bark should not be pressed down very close, as that would too much prevent its heating. The dung employed should be mixed with litter, and not more than three or four weeks old. A strong hotbed should be four feet deep in dung; but for those which are made late in the season, as in March or April, a depth of two feet will suffice. The depth of soil on the top of hotbeds, must be accommodated to what the plants will require, and must therefore be varied from six to twelve inches. It should so completely cover the dung, that none of the steam from the latter can escape, except by passing through it. The beds ought to be made on a dry place, and on level ground, to admit of fresh dung being applied round them, when they begin to cool.

The hotbed is completed by placing over it a rectangular frame of wood, with a cover inclined like the roof of a hothouse, and glazed; the depth of the frame at the back, which is directed towards the north; is generally twice the depth of the front, and the bed on which it is placed is level. Hence the plants at the front are generally too near the glass, while those at the back are too distant from it; but if the frame be made of the same height all round, and be placed upon an

inclined bed of earth, every inconvenience will be obviated, and the expense of the frame much diminished. In a frame of this kind, Knight ripened grapes, by introducing the branches of a vine through holes at the north end of it, when the frame was three feet from the vine, which was trained to a south wall. For grapes, the depth of the frame should not be less than eighteen inches, though seven or eight inches will answer for seeds; pine plants require a height of three feet.

CATALOGUE OF PLANTS USUALLY CULTIVATED IN GARDENS.

Flower Garden.

Tender Annual Flowers.

The seeds of plants of this description are sown upon a strong hotbed, at the latter end of February, in March, or the beginning of April; in the course of a month or six weeks, they are thinned; in May they are put into pots, and in June, if the weather be mild, they may be kept in the open air, but still kept in pots, as it may be desirable to set them in the green-house, during very unfavourable weather.

Amaranths
Balsams
Cockscombs
Egg-plants
Humble plant
Ice plant
Martynia
Scarlet convolvolus
Sensitive plant
Snake melon
Stramoniums

Less tender Annual Flowers.

These flowers require only a moderate hotbed; their seeds are sown in March or April, and when mild weather commences, they are transplanted, first into pots, and afterwards into the flower-borders.

African marigold
Basil
Browallia, blue,
Cape marigold
Capsicum
Chinese aster
Chinese hollyhock
Chinese, or Indian pink
Chrysanthemum
Convolvulus
French marigold
Gourds

Less tender Annual Flowers, (continued.)

Indian corn
Lennia
Love-apple
Lychnis
Marvel of Peru
Mignonette
Nolana
Palmachristi
Persicaria
Stocks
Sultan, yellow,
Tobacco
Tree amaranthus
Zinnia

Hardy Annual Flowers.

To be sown in March or April, and the seeds to be gathered as they ripen, for the next year. These flowers require to be frequently watered in dry weather.

Adonis
Alkebengi
Alysson
Amaranth
Amythystea
Balm, Moldavian,
Belvidere
Candytuft
Carthamus
Catchfly, Lobel's,
Caterpillar trefoil
Clary, red and white,
Convolvulus major
Cornbottle
Cucumber, spurting,
Fumatory, yellow,
Hedgehog trefoil
Honeywort
Indian corn
Ketmia
Larkspur
Lavatera
Lupines
Mallow
Marigold, garden,
Mignonette
Nasturtium
Nigella
Pansey, or heart's ease
Pease, sweet-scented,
Persicaria
Poppy
Safflower
Scarlet bean
Starry scabious
Stock, small,
Stock July-flower
Strawberry spinach
Sunflower
Tangier pea
Venus's looking-glass
Xeranthemum

Biennial Flowers.

To be sown in March, April, or May; to be thinned and transplanted in July, and in September to be placed in borders of the flower-garden. In the second summer, they flower, perfect their seed, and die; or if a plant accidentally survive till the following year, it is poor and worthless; the succession of them must therefore be preserved by annual sowing.

Canterbury bell
China pink
Colutea, Ethiopian,
Common pink
French honeysuckle
Globe thistle
Hollyhock
Mallow tree
Poppy, yellow horned,
Rocket
Scabious
Stock July-flower
Sweet-william
Tree primrose
Vervain mallow
Wall-flower.

Perennial Flowers.

Most perennial flowers are propagated by offsets, or parting of the roots, in spring or autumn, taking care that each piece separated has some fibres of root: this is usually done in September, and the slip of the root will itself flower the ensuing summer; if done in spring, it should precede the shooting of the stalks.—The flowers which are mostly propagated from seed, are marked thus†

Adonis
Alysson†
Anemone
Asphodel
Asters
Auricula
Bachelor's button
Bean caper
Bee larkspur†
Bugloss
Campanula†
Carnation†
Campion
Cardinal flower
Cassia
Columbine†
Cowslip
Cranesbill
Crowfoot
Daffodil
Daisies
Dogtooth violet
Dragons
Dropwort
Eternal-flower
Fennel giant
Feverfew
Flax
Fleur-de-luce
Foxglove†
Fraxinella
Fumatory
Garlic
Gentianella
Golden locks
Golden rod
Greek valerian
Hawkweed†
Hepatica
Herb bennet
Hollyhock†
Houseleek
Lady's mantle
Lady's slipper
Lady's smock
Lily of the valley
Lion's tail
London pride
Loose-strife
Lupine
Lychnis
Lychnidea
Madwort
Marsh marigold

Perennial Flowers, (continued.)

Meadow-sweet
Milfoil
Milk-vetch
Mint
Moth-mullen
Navelwort
Ox-eye daisy †
Pea, everlasting †
Peony
Pilewort
Pinks
Plantain
Polyanthus †
Primrose
Ragged Robin
Ranunculus
Reed
Rhubarb †
Saxifrage
Skullcap
Snap-dragon †
Sneezewort
Side-saddle flower
Soapwort
Solomon's seal
Spiderwort
Spurge
Stonecrop
Sunflower
Swallow-wort
Thrift
Throatwort
Toadflax
Tradescantia
True love
Valerian
Vervain
Veronica
Violet
Viper's bugloss
Wake robin
Willow herb.

Bulbous and Tuberose-rooted Flowers.

A bulbous root, of which an onion is an example, is in fact a bud containing the parts of the future plant already formed —leaves, stalk and flower; but a tuberose root, as exemplified in the turnip and carrot, consists of a uniform fleshy substance. Roots of both kinds are to be taken up, as soon as they have done flowering, and their leaves are withered. By this means, they flower the next season with greater vigour; they are kept out of the earth, and the powers of vegetation are dormant, generally from two to three months. They are most easily multiplied by offsets, which are small, but in other respects like the parent, whether that be bulbous or tuberose. The offsets should be separated from the main root at the time they are taken up, which should be done in dry weather.

Aconites
Amaryllis
Anemone
Asphodel
Bulbocodium
Colchium
Corn-flag
Crown imperial
Cyclamen
Daffodil
Fretillaria
Fumatory

Bulbous and Tuberose-rooted Flowers, (continued.)

Hyacinth
Iris
Jonquil
Narcissus
Pancratiums
Polyanthus Narcissus
Ranunculus
Saffron
Sisyrinchium
Snowdrop
Squill
Star of Bethlehem
Tuberoses
Tulips

Kitchen Garden.

Angelica
Anise
Artichoke, Dutch or globe
French
Jerusalem
Asparagus
Balm
Basil, sweet
Bean, dwarf
French
kidney
Lisbon
long-podded
mazagan
red-blossomed
Sandwich
Spanish
white-blossomed
Windsor
Beet, green
red
white
Borecole
Borage
Broccoli, cauliflower
early purple
late purple
Cabbage, drum head
imperial
sea
sugar-loaf
Scotch
Cabbage, turnip-rooted
Cardoon
Carrot
Capsicum
Cauliflower
Celery, common
upright
Chamomile
Chives
Chervil
Clary
Coriander
Corn-salad
Cress
Cucumber, short green, early,
long green, prickly
Dutch white
Roman
Turkey green
white
Dill
Elecampane
Endive, green curled
white
Batavian
Eschalot
Fennel
Garlic
Gourd
Horse-radish
Hyssop
Indian-cress

Kitchen Garden Plants, (continued.)

Kale
Lavender
Leek
Lettuce, black coss
brown Dutch
early green cabbage
white cabbage
imperial
Silesian
green coss
white coss
Love-apple
Marjoram, annual sweet
winter peren. sweet
Marigold
Melons, cantaleupe
Roman
Mint, pepper
spear
Mushroom
Mustard, black
white
Onion, Portugal
Spanish
Strasburgh
Welch
Orache
Parsley, common
curled
broad-leaved
Parsnip
Pea, Charlton
golden
Reading hotspur
Spanish
green nonpareil
marrowfat, large
dwarf
rouncival
egg
sugar
Pennyroyal
Potato, common red
Potato, common red, early
kidney, early
American
Purslain, green
golden
Rampion
Radish, long-topped
short-topped
salmon
Spanish white
black
Rape
Rhubarb
Rocambole
Rosemary
Rue
Saffron
Sage, common
red
broad-leaved
narrow-leaved
Salsafy
Savory, summer
winter
Savoy, green
yellow
Scorzonera
Skirret
Sorrel, common
French
Spinach
Tansey
Tarragon
Thyme
Turnip, early Dutch
oblong
green
red
yellow
white-rooted French
Water-cress
Wormwood

FRUIT GARDEN.

Almond, common
dwarf
Jordan
white-flowered
Apple, codlin, common
June-eating
Margaret
Kentish
Winter pearmain
Summer pearmain
queening
rembourge
scarlet summer
quince
Loan's pearmain
royal pearmain
golden pippin
rennet
russet
redstreak
white rennette
Kentish pippin
nonpareil
nonsuch
Wheeler's russet
kitchen rennette
fig
quince
Apricot, Breda
early
orange
peach
red
transparent
Turkey
white
Barberry, black
stoneless
white
Cherry, common black
Kentish, red
May-duke
Cherry, archduke
white-heart
red-heart
black-heart
amber-heart
ox-heart
bleeding-heart
carnation-coloured
Morello
Turkey
Portugal
Currants, common red
white
white grape
black
Fig, common blue
black ischia
green ischia
brown ischia
Genoa
Malta
Marseilles
Naples
Gooseberry, hairy red
smooth red
damson
red raspberry
early black
hairy green
smooth green
green Gascoigne
green raspberry
great oval yellow
great amber
early amber
large white crystal
common white
rumbullion
great mogul
Grape, July
royal muscadine
Malmsey muscadine

Fruit Garden, (continued.)

Grape, black muscadine
common muscadine
white muscat
red muscat
black muscadel
red muscadel
black Damascus
Frontiniac
Lisbon
Spanish
Tripoli
red Frontiniac
white Frontiniac
red Hamburgh
white Hamburgh
early white Teneriffe
red Syracusan
Morocco
blue Tokay
white Tokay
claret
Burgundy
Medlar, German
Nottingham
Italian
Mulberry, black
Nectarine, Fairchild's early
violet
elrouge
Newington
red Roman
scarlet
Italian
golden
Peterborough
early nutmeg
Nut-tree, common hazel
large cluster wood
cob
long
Barcelona
dwarf Byzantine
Peach, early white nutmeg
red nutmeg
Peach, great mignon
early purple
White Magdalen
red Magdalen
early Newington
Montauban
noblesse
chancellor
Rambouillet
royal George
Catharine
Cambray

Summer Pears.

Pear, musk
green chisel
red muscadelle
jargonelle
Windsor
queen's
orange musk
royal
summer bon chretien
bergamotte, orange
summer

Autumn Pears.

Pear, autumn
Swis
caraway
brown beurre
white beurre
green sugar
swan's egg
twice-flowering

Winter Pears.

Pear, St. Germain
Chaumontelle
Colmar
Spanish bon chretien
dauphin
Holland's bergamotte
Worcester black

Fruit Garden, (continued.)

Pear, double-flowered
Plum, damask, early black
little
great
black
damson
green gage
blue gage
Orleans
perdigron, black
blue
white
Mogul, or egg
imperial
apricot
pear
damascene
Plum, bullace
Quince, apple
pear
Portugal
Raspberry, common red
white
double-bearing
white Antwerp
red Antwerp
Strawberry, alpine
Chili
hautboy
scarlet
Walnut, thin-shelled
thick-shelled
double
common oval

GREENHOUSE PLANTS.

Adam's needle
Alaternoide Clutea
Aloe
Amber-tree
Arctotis
Asparagus
Asphodel lily
Aster, African
Atraphaxis
Balm of Gilead
Bay-tree
Bead-tree
Bean caper
Bell-flower
Bird's foot trefoil
Birthwort
Bladder sena
Blood-flower
Blue lobelia
Boxthorn
Briony, African
Buckthorn
Buddleia
Burnet
Butcher's broom
Camphire tree
Caper shrub
Canary convolvulus
flower
lavender
Candy-tuft
Cape marigold
Cassine
Catch-fly
Ceanothus
Chrysanthemum
Cistus
Citron
Clethra
Climbing Mediola
Coral-tree
Corn-flag, Ethiopian
Corn-flax
Crassula
Cyclamen
Ebony

Greenhouse Plants, (continued.)

Euphorbia
Fig-marigold
Fig-tree
Flea-bane, African
Foreign coltsfoot
Foxglove
Furze, African
Geranium
Germander-tree
Gnaphalium
Goldilocks
Grewia
Groundsel, African
Hare's ear
Honeysuckle
House-leek
Indian flowering reed
Indigo
Indian cress
Inula
Iron wort
Ixia
Jasmine
Jerusalem sage
Keggelaria, African
Knee-holly
Lavender
Lemon
Lesser orpine
Lion's tail
Macedonian parsley
Malabar nut-tree
Mallow
Marvel of Peru
Melon thistle
Milk-vetch
Milkwort
Morea
Mugwort
Myrtle
Navel-wort
Nightshade
Oleander
Olive-tree
Orange
Origany
Ox-eye
Phlomis
Pimpernel
Pistachia tree
Ploughman's spikenard
Pomegranate tree
Purslane
Ragwort
Rest-harrow
Rock-rose
Rough bindweed
Sage
St. John's wort
Scabious
Sensitive plant
Shrubby hedge-nettle
Silver tree
Silvery convolvulus
Snap-dragon
Sorrel-tree
Sparrow-wort
Speedwell
Spider-wort
Staff-tree
Star of Bethlehem
Starwort
Strawberry-tree
Sumach
Sweet calla
Swallow-wort
Tansey, Ethiopian
Tetragonia
Tooth-ach tree
Tree mint
Trumpet-flower
Turnsol
Vervain
Viburnum, American
Viper's bugloss
Virginian silk
Xeranthemum
Yerva mora

Hothouse Plants.

Acanthus
Achyranthes
Adam's needle
Adenanthera
Aloe, African
    Guinea
Amaryllis
Arrow-root, Indian
Asphodel lily
Balsam of Tolu-tree
Bamboo-cane
Bead-tree
Blood-flower
Bread-tree
Brunsfelsia
Buckthorn
Buddleia
Cabbage-tree
Calabash-tree
Cardinal-tree
Carica
Cassada
Cassia
Cherry, Barbadoes
Chocolate-nut-tree
Cinnamon-tree
Clutia
Cocoa plum
Cocoa-nut-tree
Coffee-tree
Coral-tree
Cotton-plant
Custard-apple
Date-tree
Dog's-bane
Dragon-tree
Dwarf palm
Dying metella
Elephant's foot
Ethiopian sour gourd
Euphorbia
Fiddle-wood
Fig-marigold
Fig-tree
Flower-fence, Barbadoes
Galangale
Garland flower
Geoffroya
Ginger
Grewia
Guinea-pepper
Hibiscus
Hyacinth, Indian
Iron-wood
Jack-in-a-box tree
Jasmine, red
    Arabian
    Cape
Jasminoide
Lead-wort
Lily-thorn
Logwood-tree
Looking-glass plant
Madagascar rose
Mahogany-tree
Malabar-nut
Mammee-tree
Mango-tree
Martynia
Mastic-tree
Melon-thistle
Mountain ebony
Myrtle-tree
Navel-wort
New Jersey tea
Nightshade, Malabar
Oleander
Olive, Barbadoes
Passion-flower
Periwinkle
Pepper
Peruvian bark-tree

Hothouse Plants, (continued.)

Pine-apple
Plantain-tree
Rivinia
Robinia
Sand-box tree
Scarlet campion
Screw-tree
Sea-daffodil
Sensitive plant
Shrub-trefoil
Silk cotton-tree
Snow-berry
Spurge
Star-apple
Sugar-cane
Sumach
Superb lily
Swallow-wort
Syrian-mallow
Tallow-tree
Tamarind-tree
Tournefortia
Tree celandine
Triumfetta
Trumpet-flower
Turmeric
Turneria
Urena
Viburnum, American
Vine
Virginia silk
Volkameria
Wake-robin
Waltheria
Wild olive, Barbadoes
Winteramia
Ximenia
Zamia

Deciduous Trees and Shrubs.

Acacia
Alder
Almond
Althæ-frutex
Andromeda
Ash
Arbor-judæ
Azelea
Azerole
Barba-jovis
Barberry
Bastaria
Beech
Benjamin
Bignonia
Birch
Bird-cherry
Bladder-nut
Bramble
Bush-cassiberry
Catipha
Cephalanthus
Cherry
Chesnut
Chionanthus
Cinquefoil shrub
Clathea Celtis
Coccigria
Colutea
Cretægus
Cypress
Dogwood
Elde
Elm
Empatrum
Filbert
Flamula-jovis
Frangula
Fringe-tree
Gale

Deciduous Trees and Shrubs, (continued.)

Guelder-rose
Hazel
Hamamelis
Hawthorn
Hickory
Honeysuckle, or woodbine
Hornbeam
Hydrangea
Hypericum-frutex
Itea
Jasmine
Kidneybean-tree
Laburnum
Larch
Laurustinus, African
Lavender
Licium
Lilac
Lime
Liquidamber
Louisera
Maple
Medlar
Melia
Mevispernum
Mezereon
Myrtle
Naples medlar
Oak
Oleaster
Palmirus
Peach
Pear
Periploca
Persamen plum
Plane
Pomegranate
Poplar
Privet, common
Privos
Ptelen
Rhamnus
Robinia
Rose, 80 varieties
St. Peter's wort
Sassafras
Scorpion sena
Service
Silver-ivy
Smilax
Spiræa
Styrax
Sumach
Sycamore
Syringa
Tacamahacca
Tallow-tree
Tamarisk
Toothach-tree
Toxicodendron
Tupelo-tree
Uoleosia
Varnish-tree
Walnut-tree
Willow
Xanthoxylum

EVERGREEN TREES AND SHRUBS.

Alaternus
Andromeda
Arbor-vitæ
Arbutus
Bay
Bignonia
Box
Broom
Cedar
Cistus
Cork
Coronilla

Evergreen Trees and Shrubs, (continued.)

Cypress	Mespilus
Enonymus	Oak
Fir	Phillyrea
Furze	Phinius
Germander	Pine
Groundsel, Virginian	Privet
Hartwort	Prinos
Holly	Purslane-tree
Horsetail	Pyracantha
Honeysuckle, trumpet-flowered	Ragwort, sea
Ivy	Rhododendron
Jasmine, Italian	Rose, evergreen
Juniper	Savin
Kalma	Spurge
Kneeholme	Staff-tree
Laurel	Stonecrop-tree
Laurustinus	Tutsan
Lavender cotton	Widow-wail
Lotus	Wormwood
Magnolia	Yew
Medicago	Yucca

THE GARDENER'S CALENDAR, OR MONTHLY COURSE OF LABOUR.

First Month of the Year.—January.

In the Flower Garden and Shrubbery.—Plant crocusses, tulips, snowdrops, and other bulbous roots. Plant flowering shrubs, and box and other edgings: prune flowering shrubs, taking care to remove their suckers. Protect tulips, hyacinths, and other delicate flowers, from cold weather and heavy rains, by coverings of litter or mats. Plant hedges and ornamental trees. In open weather, dig over the shrubbery, and remove moss.

In the Kitchen Garden.—Prepare hotbeds for early melons, cucumbers, onions, cresses, mustard, and radishes. Cover mushroom-beds with straw, heath, &c. particularly during frost. Plant asparagus in hotbeds, and give it air, except in stormy weather. Sow pease, beans, carrots, cabbage-lettuces, and curled parsley. Provide for the succession of pease and

beans, by sowing at intervals of a fortnight. Sow spinach; earth up celery and broccoli. Pick the decayed leaves from cauliflowers standing under glasses, and give them air at midday if the sun shines. In frosty weather, when other work is hindered, wheel in dung, examine trees for the nests of caterpillars, and seek out the harbours of snails and other vermin.

In the Fruit Garden.—Loosen espalier and wall fruit-trees, and in open weather, prune apple, pear, and quince trees; vines, gooseberries, currants, and raspberries, removing all cankered and decayed branches, and scraping off moss with a blunt iron tool. If the weather be very cold, spread rotten dung or straw, or the refuse of flax, over the roots of the trees, not immediately at the bottom of the trunk, but principally over the small roots at a distance; for the roots of trees generally extend as far as their branches. Plant new strawberry beds; prepare hotbeds for raising the early scarlet strawberry. Cut grafts before the buds become large.

In the Greenhouse.—Both in frosty and damp or foggy weather, employ small fires. During the warmest part of every fine day, open the sashes, in order that the air in the house may be kept constantly sweet. Be extremely sparing of the use of water; aloes, and other succulent plants, will require none. The water should have acquired the temperature of the house before it is used. Fumigate occasionally with tobacco smoke.

In the Hothouse.—Carefully regulate the fires, according to the state of the weather. The temperature of the house, during the night, to be kept about 55 degrees of Fahrenheit, and in the middle of the day it should rise to about 70 degrees. Admit fresh air every day. Remove all insects that can be found, particularly examining for them the blossoms of fruit-trees. Roses and other flowers will frequently require water, but fruit-trees in blossom only seldom, and little at a time.

In the Nursery.—Repair the fences, to keep out rabbits, hares, and other animals, which are at this time very destructive, from the scarcity of food. Transplant and prune forest-trees and flowering shrubs. Trench the ground for sowing seeds in spring: make plantations of stocks for budding and grafting upon. Gather and carry away the moss, wherever it appears.

Second Month.—February.

Flower Garden and Shrubbery.—Finish the planting of box and other edgings. Lay down turf where it is required, and in order to prevent the grass from becoming rank, if brought from a poor to a rich soil, place under it a layer of sand. Bulbous and tuberose-rooted flowers may still be planted, but will in general be weaker than if planted in the fall of the year. Dig over and manure the soil of the shrubbery, and finish the pruning of the shrubs. Transplant perennial flowers; sow tender annuals in hot-beds, and prepare the ground for sowing hardy annuals. Continue to cover beds of valuable flowers with mats as in last month, taking off the mats in the middle of the day. Sweep off the moss from gravel walks, with a stiff broom.

Kitchen Garden.—Sow melons, cresses, mustard, radishes, and celery. Put the cucumbers three days old into small pots, one for each plant, and put the pots up to the rim in a hotbed. Continue to sow pease, beans, carrots, cabbages, savoys, and lettuces. Examine the cauliflowers and lettuces under glasses. Earth up the beans and pease of last month's sowing. Plant gaılic, rocambole, chives, eschalots, scorzonera, salsafy, borage, angelica, marigold, curled parsley, potatoes, and Jerusalem artichokes. Plant horse-radish by cuttings; and at the end of the month, plant the last crop of asparagus for forcing. If the heat of any of the hotbeds appears to decline too much, remove a part of the dung round the sides, and apply a quantity of fresh.

Fruit Garden.—Prune and nail up vines, peaches, nectarines, and other stone-fruit trees. Transplant fruit-trees of all sorts. Plant cuttings of gooseberries and currants. Give air to strawberries on hotbeds. Graft apples, pears, plums, and cherries. If gum or symptoms of canker appear, cut out the infected part.

Greenhouse.—As mild weather occurs or approaches, admit more or less fresh air during the day. Dissipate the damp of foggy weather, and ward off the effects of frost, by small fires. The aloe will still require no water; plants of a less succulent nature will require a little; and others, in proportion as they approach to a hard or ligneous texture, will require the quantity of water to be increased. Frequent waterings are better than few and copious ones. Remove all decayed leaves. Remove the earth of pots to the depth of an inch, and supply its place by fresh mould.

Hothouse.—Let the temperature be about 55 degrees during the night, and 75 or 80 degrees during the middle of the day. Thin the bunches of grapes; eradicate decayed leaves and insects. Take care to keep the air in a wholesome state. Frequently water pines, stir up the old bark, and mix with it some fresh, if there be a decay of its heat. Fumigate to destroy insects.

Nursery.—Plant acorns, beech-mast, and other seeds, &c. of shrubs and forest trees: cut down seedling chesnuts of one year old to the ground: head down grafted and budded stocks; plant cuttings, suckers, and layers in general.

Third Month.—March.

Flower Garden and Shrubbery.—Give a covering of fresh earth to plants in pots, first removing a layer of the old earth. Roll gravel walks:—Finish the planting of deciduous shrubs, and perennial flowers, and continue to sow annual flowers, to maintain a succession of them. Tender annuals, sown in pots, will require a gentle hotbed, to hasten their time of flowering. Sedulously weed the flower borders. Plant evergreens with balls of earth. Plant carnation layers in pots. Shelter tender flowers from heavy rain or sleet. Finish the laying of turf, and at the end of the month mow the grass.

Kitchen Garden.—Sow the general crop of lettuces, parsnips, and carrots. Continue to sow pease and beans at intervals. Sow spinach and cabbage seed, celery, and early turnips. Make fresh plantations of asparagus, between the rows of which sow onions. Remove the hand-glasses from cauli flowers, and earth them up. Sow salading, parsley, horse radish, thyme, and aromatic and physical herbs in general Plant leeks and endive for seed. Surround the hotbeds of melons and cucumbers with a thick lining of fresh dung, or remove them to fresh beds. Kidney-beans, Jerusalem artichokes, tomatoe, mushrooms, and capsicums, must not be forgotten.

Fruit Garden.—The blossoms of the peach, nectarine, and apricot, must be protected from dry and cold winds in the night, by placing hurdles before them, or spreading old fishing nets over them, or covering them with mats. Plant and prune; graft the various kinds of stocks; shorten the shoots from the grafts of last year, and take off the heads of the budded stocks of the same age. Dress strawberry beds, and water them, especially those on hot-beds; place wisps of straw on the ground to support the leaves, and remove all runners, unless it is

intended to prepare for a new plantation of them in autumn. Hoe the soil where the currants and gooseberries are planted.

Greenhouse.—Trim myrtles, orange-trees, lemon-trees, and other shrubs, to the form required. Open the sashes during the warmest part of all fine days. Frequent waterings will be required; and the washing of the plants with water is beneficial. Exclude the frost; for which purpose, at nights, a small fire will be necessary. Sow the seeds of greenhouse plants in hotbeds.

Hothouse.—Thin the leaves and shoots of the vine. Admit fresh air during the middle of fine days. To maintain the heat in a regular manner is of great consequence to the pines, which will now begin to shew fruit. The temperature in the morning should be 60 degrees, and in the course of the day, should rise to 75 or 80 degrees. Daily remove weeds, decayed leaves, and insects, and water the plants and hot flues.

Nursery.—Plant the layers and cuttings of deciduous trees and shrubs, and sow the seeds of the same kinds. Trench the ground intended to be sown with seeds. Perform the grafting required. Transplant the poplars raised from cuttings to moist ground. Seed-beds require watering if the weather be very dry; or else the earth should be kept moist with branches of fern, furze, yew, or fir, kept spread over it till rain occurs.

Fourth Month.—April.

Flower Garden and Shrubbery.—Finish the rolling of gravel walks, as also the repairing, rolling, and mowing of grass lawns and walks. Finish the planting of perennials and biennials, and still continue the sowing of annuals. Weed the flower borders. Stir up and dress the soil of flowers and shrubs in pots. Finish the planting of evergreens and shrubs. Clip box and other edgings; support the tall-growing herbaceous or flowering plants with sticks. Protect auriculas, tulips, and other delicate flowers, from heavy rain, high winds, and strong sunshine; for this purpose, an arch should be made of hoops, to support the mats, or other covering. Carnations and polyanthuses may yet be sown, and edgings may yet be planted, but the latter will occasion some trouble in watering, if the weather prove dry.

Kitchen Garden.—As soon as the last-sown pease and beans appear above ground, sow again to keep up the succession. Continue to sow radishes, spinach, cresses, mustard, broccoli, and lettuces, and cardoons to transplant. Draw the earth up to cabbages, cauliflowers, and the pease and beans sown early

last month. Sow kidney-beans. Finish the planting of aromatic and medicinal herbs. Sow more turnips, scorzonera, salsafy, celery, and parsley. Weed the beds of onions, lettuces, carrots, and leeks. After rain, look out for snails and slugs, or turn in some ducks for a short time, and they will perform the business without injuring the vegetables. Pinch off the ends of melons which have two or three joints, to cause them to throw out runners. Take off the young shoots of artichokes, and the tops of beans in flower. Never suffer melons and cucumbers to flower near together, as they are plants of the same genus, and would cause each other to degenerate.

Fruit Garden.—Finish planting and pruning. Examine budded and grafted trees, to take off all the shoots proceeding from the stock, and close the fissures observed in the grafting clay. Water frequently, in case the weather be dry. If any trees are blighted, mix hog's dung with the soil as far as the roots extend, and water freely. Thin the fruit of apricots. Search diligently for caterpillars, of which numbers will now be found crowded together, and if the work of destroying them be delayed, they will soon spread over the trees. Weed the strawberry beds. Plant cuttings of vines.

Greenhouse.—Give air, and water freely. Set geraniums very near the window. Remove myrtles and the hardiest kinds of greenhouse plants, to warm situations in the open air. Inoculate orange and lemon trees. Remove the moss from the mould of plants in pots.

Hothouse.—Regularly train the vines, and thin the leaves where they would shade the fruit. Water pine-apples frequently. Admit air every fine day. Have fires during the night, and on damp gloomy days. Plant seeds, cuttings, layers, and suckers, of all the stove-plants to be propagated.

Nursery.—Sow the seeds of larches, firs, and pines, and transplant seedlings of these kinds. Hoe the chesnut ground, and water all trees and shrubs, if the weather be dry. Sow the seeds of roses, sweet-briar, and tender trees and shrubs in general.

Fifth Month.—May.

Flower Garden and Shrubbery.—Take up all bulbous roots of which the leaves are withered. Put auriculas which have flowered into fresh pots, and set them in the shade, but not under the drip of trees. Trim carnations, and stake them. Remove balsams, egg-plants, sensitive plants, and other tender annuals, to a fresh hotbed. Mignonette, and all the less tender

annuals, may now be planted out in patches on the flower borders, and the seeds of hardy annuals and biennials may be sown to keep up the succession. When there is a probability of rain, transplant perennials from the seed-beds. Carefully attend to rose-trees, to free them from insects: fumigations of tobacco, or water in which tobacco has been steeped, will destroy all the soft green insects. Plant tuberoses for blowing in autumn: water newly planted shrubs; and never suffer a weed to flower.

Kitchen Garden.—Give air to the hotbeds during the day; but keep up the heat of those containing cucumbers and melons, by fresh linings of litter. Place tiles under the melons as they set, to prevent the moisture of the bed from staining the fruit. Earth up pease and beans, and cut the tops off the latter, when in flower. Prick out celery, sow the large sorts of kidney-beans, and continue to sow the common kind, and pease. Sow cresses and mustard, thinly, for seed. Plant out capsicums for pickling. Transplant cabbages and savoys for winter. Transplant lettuces, and sow more seed. Select some of the finest radishes for seed. Thin cardoons; hoe onions, carrots, parsneps, and turnips. Sow beets, and the principal crop of broccoli. Plant out cucumbers, which, when trained against a south wall, have a finer flavour than when suffered to creep along the ground. Thin the first crop, and sow the second of endive. Propagate aromatic herbs, by slips or cuttings. In dry weather, frequent watering will be required.

Fruit Garden.—Pull off all buds which appear in improper places; thin apricots for the second time, and nectarines and peaches for the first time. Search for snails and caterpillars, pinch curled leaves, and fumigate where it appears necessary. Take off the clay from grafts perfectly united to the stock. Prune fig-trees, if not done last month. Weed and dress strawberry beds. A liberal supply of water will be required in dry weather.

Greenhouse.—Inure the plants to a free circulation of air; water frequently. Finish sowing greenhouse plants. Propagate by layers and cuttings. Remove to larger pots or tubs, the plants which require it, and towards the end of the month, if the season be mild, set in the open air the remainder of the plants which are esteemed moderately hardy.

Hothouse.—Pines will require much attention; water them frequently; if the heat of the bark decline, put some fresh into the bins. Make fires in damp weather, and at night, unless in a very mild season. Propagate stove exotics by seeds, cuttings, layers, and suckers. Let the temperature of all the water used be equal to that of the house, and give air occasionally

Nursery.—Dress the seedling beds, and remove weeds, which will now grow rapidly, and prove very injurious, if allowed to remain. Water frequently. Dig over the ground of new hedges. Arch the beds with hoops, to support mats for covering seedlings during the hottest part of the day, when the sun is powerful.

SIXTH MONTH.—JUNE.

Flower Garden and Shrubbery.—Attend to bulbous roots which require taking up. When taken up, they must not be crowded together in earthen or iron pots, where they will mildew, but after lying a few days on mats or a dry boarded floor, they should be put into drawers, or hung up in paper bags, in a dry apartment. Plant out annuals from hot-beds, in wet weather if possible, to spare the trouble of watering. Transplant seedling perennials. Clip box and other edgings, and evergreens in general, in moist weather. After trimming the shrubs, hoe the ground. Cut down and remove the stalks of perennials which have done flowering. Weed and roll gravel walks, and mow the grass of lawns. Sow annuals to flower in autumn. Increase carnations and pinks by layers or cuttings. Plant bulbous roots, which are to blow in autumn. Stake and tie up flowering plants that spread too widely.

Kitchen Garden.—Sow beans, and hotspur and dwarf marrowfat pease, in moist ground; and if the weather be dry, prepare the seed by steeping it in water for six or eight hours. Plant out the melons raised in pots for hand-glasses; cover with mats those in frames during the hottest part of the day. Nail up the runners of cucumbers trained against walls. Sow lettuces and endive for autumn, and sow purple and cauliflower broccoli for winter's use, four times, at intervals of three weeks or a month. Make the last sowing of savoys, and prick out broccoli, cabbages, cauliflowers, and celery. Hoe and set out to their proper distances, turnips, onions, carrots, and parsneps. Increase marjoram, thyme, and other aromatic and pot-herbs by slips, and gather before they flower those of which the leaves only are required. Dress the asparagus beds. Sow rape and coleseed. Water freely.

Fruit Garden.—Cut off all the superfluous shoots of espaliers and wall-fruit trees, and train the shoots reserved to their proper distances; taking care that the nails never touch the fruit, or hinder it from swelling. Thin the fruit branches and leaves of apricots for the last time. Bud stone-fruit trees. Destroy

insects. Rub off the useless buds of the vine, removing always the weakest. Water the blighted and newly planted trees, and strawberries in flower; clear the strawberries from suckers. To have strawberries in autumn, cut off the heads of those just beginning to flower.

Greenhouse.—Admit air very freely, and, if the season be not very backward, leave the sashes open all night. All but the most delicate greenhouse plants may be set out; oranges and lemons may be inarched; these trees are frequently kept in the greenhouse the whole year, to screen them better from the effects of changeable weather. Propagate by cuttings and layers. The cuttings of succulent plants should be allowed a week or two to dry before they are planted. Cover the surface of pots with fresh soil every month, removing a layer of the old for that purpose, and stir it up occasionally in the intervals.

Hothouse.—Maintain a high temperature, which will in the sunshine at noon generally rise to 95 degrees, if in the morning it is above 60 degrees. To make the liberal admission of fresh air comport with this heat, fires will occasionally be necessary. Water frequently, with water at the temperature of the house. Train the shoots of the vine required for next year's fruit.

Nursery.—Weed the young stocks designed for grafting, and remove from them suckers and moss. Examine and weed the beds of seedlings and quicks. Inoculate roses, apricots, peaches, and nectarines; examine last year's grafts; transplant seedling pines and firs. Water frequently, if the weather be dry.

SEVENTH MONTH.—JULY.

Flower Garden and Shrubbery.—Transplant the seedling auriculas and polyanthuses, and the first layers of pinks and carnations; transplant seedling perennials into nursery beds, as they become too thick. Plant cuttings of scarlet lychnis, sweet-williams, pinks, and rockets, in a shady border, and keep them covered with glasses, till they have grown two or three inches. Remove the glasses over balsams, egg-plants, and other tender annuals, and put fresh earth on the top of each pot. Take up lilies, crown imperials, &c. to separate offsets. Transplant seedling bulbs of two years old, which have not yet been removed. Gather seeds as they become ripe. Bud roses, variegated hollies, and jasmines. Transplant ever-

greens; water frequently the myrtles placed against walls. Hoe and dress more or less daily.

Kitchen Garden.—Plant the principal crop of cabbages and endive, and the last crop of kidney-beans; transplant the second crop of savoys, and the first of broccoli, and prick out the second crop of broccoli from the seedbeds. Thin the cauliflowers sown in May, and pricked out the last month, by transplanting about half of them. Take up garlic, eschalots, rocambole, and onions, when their leaves are withered. Sow lettuces and carrots for autumn. Earth up capsicums, the cucumbers sown last month, and the first crop of celery. Sow turnips on a moist bed. Pull off the side shoots of artichokes. Shelter melons with glasses from the heat of the sun in the middle of the day, giving them but little water while ripening, but stirring the soil about them, and destroying weeds. Sow pease for a late crop, also spinach in small quantities at a time, as it quickly runs up to seed. Gather flowers and leaves for drying and distilling.

Fruit Garden.—Peaches, nectarines, fig-trees, pears, cherries, and plums, must be inspected once a week, to nail up the shoots for next year's fruit, and remove whatever is superfluous. Stirring up the soil will refresh these trees, and mixing with it hog's dung will be serviceable, if blight is observed. Bud stone-fruit trees. Great numbers of ants, wasps, and other insects, may be destroyed by hanging up bottles half filled with sugar and water, but this must be done before the fruit is ripe, or it will not be fully effective. Take off the runners of strawberries, when they are not required for a new plantation. The ripening of currants may be protracted for two months, by a covering of mats. Search for snails and slugs in the evening, after rain.

Greenhouse.—Weed and dress more or less daily, taking off all shoots that detract from the neat appearance of the plants. Aloes and other succulent plants may be set in the open air. As the greenhouse will now be nearly empty, it may in part be replenished, by bringing from the hothouse, such flowers and shrubs as will either be benefited or not injured by a fresher and cooler air. Aloes and other succulents, may be propagated by slips; oranges and lemons may be budded, and the fruit of those which bear may be thinned. Watering will be frequently required, especially by fruit-bearing trees. Paint and white-wash the greenhouse.

Hothouse.—Admit air freely during the day, and also during the night, unless the weather be gloomy and cold, in which case the pines will require the assistance of a little fire. Take care that the heat of the bark be well maintained, but not vio-

lent, or it will scorch the roots. If the bark decline in heat, stir it up, sprinkle it with a little water, and let the pots be covered to the rim; if it become too hot, draw up the pots about one-third of their depth. Water the whole of the leaves and fruit of the plants, with water at the temperature of the house.

Nursery.—In moist weather, clip young hedges, and transplant the seedling firs and evergreens that are too crowded, instantly putting them into the earth again. Clear away weeds in every part, and remove suckers from the various kinds of stocks. Examine grafts, and bud stone-fruit trees, and flowering shrubs, unless the weather be very dry.

Eighth Month.—August.

Flower Garden and Shrubbery.—Plants in pots require frequent watering, particularly hotbed annuals, such as balsams, egg-plants, and cockscombs, which are about to perfect their seeds. Plant mignonette in pots to flower in winter, and set the pots in front of a south wall. Put auriculas into fresh pots, in a light soil mixed with well rotted dung: prick out seedling auriculas and polyanthuses, leaving them at the distance of three or four inches; sow fresh seeds of these flowers in boxes, and sift a quarter of an inch of earth over them. Early in the month, plant the bulbous roots that flower in autumn. Take up lilies, crown imperials, and other bulbous roots that have done flowering, before they throw out fresh fibres. Increase carnations by layers, and perennials and shrubs in general, by slips. At the end of the month, sow hardy annuals, and they will produce stronger plants than if sown in spring. Mow grass walks and lawns; weed and roll gravel walks. Continue to gather ripened seeds. Trim evergreens, edgings, and shrubs in general.

Kitchen Garden.—Sow cabbages, carrots, and corn-salad or lamb's lettuce. Dress the asparagus beds. Transplant celery. Plant out cauliflowers and turnips. Earth up cardoons, celery, broccoli, and savoys. Sow angelica, chervil, scurvy-grass, fennel, radishes, also white mustard, cress, endive, rapeseed, and lettuces. Gather mushroom spawn, and keep it in a dry place till wanted. In wet weather protect melons with glasses, or frames covered with oiled paper. Gather for pickling the cucumbers trained against a wall. Sow the prickly spinach, for winter's use, in a warm situation. Diligently pick the caterpillars from cabbages. Take up onions of which the tops are withering, and spread them out to dry, turning them

occasionally. Sow the second crop of Welsh onions. Gather seeds, and aromatic and medicinal herbs.

Fruit Garden.—Take off superfluous shoots, and leaves that shade the fruit of espaliers and wall-trees. Nail up the shoots to be reserved: destroy insects; finish budding. Refresh the roots of the trees by raking and dressing the soil. Take off the runners of strawberries. Cover the currants, of which the ripening is to be protracted. The autumnal or second crop of figs should be rubbed off as soon as it appears, which it generally does in August or September. By this means the tree will not be weakened by bearing fruit that never ripens.

Greenhouse.—Remove the plants which require it into larger vessels, and renew the surface-soil of all the pots. Propagate aloes and other succulent plants by offsets, of which each should have a small pot. Bud orange and lemon trees, and cut off from the parent stock, the branches of trees inarched in spring. The myrtles and other woody kinds of greenhouse plants will require frequent but gentle waterings.

Hothouse.—The pines will now be fast ripening; the heat of the bark must therefore be kept up: watering will be required, but it should be given most sparingly to those which are most nearly ripe. If it be required to keep back for a week or two, the ripening of a part of the pines, let them be taken out of the hothouse into the greenhouse, or even into the open air, where they should be shaded from the sun, and not watered. Shift succession pines into larger pots where they are to bear.

Nursery.—Trench and lay the ground in ridges as a preparation for the planting of next month; it will be benefited by an exposure to the air, sun, and dews. In dry weather, shrubs and seedlings will require watering. Remove weeds as fast as they appear. Examine the state of the grafted and budded trees, keeping the clay free from cracks, where it is still required, and removing it where it is no longer necessary. Trim evergreens, and transplant seedlings, watering them if there be no rain.

Ninth Month.—September.

Flower Garden and Shrubbery.—Prepare beds for snowdrops, crocuses, jonquils, tulips, hyacinths, anemones, and other bulbous roots, and plant them with a trowel in the course of the month, as they are weakened by remaining out longer Plant out perennials, and finish for the year the sowing of all the hardy annuals. Put mignonette in pots for the winter Annuals which are ripening their seeds require frequent water-

ing; balsams, egg-plants, and other tender sorts, will perfect their seeds best, if set in an alcove fronting the south, or in the greenhouse. Protect auriculas from rain. Cut down the stalks of carnations and other flowers which have flowered. Weed and roll gravel walks, and roll and mow grass lawns. In moist weather, plant box for edgings, and plant cuttings of laurels, jasmines, and all other shrubs. Gather seeds in dry weather; be particularly attentive to the radish seed, of which birds are very fond.

Kitchen Garden.—Plant out endive, cabbages, coleworts, the lettuces sown last month, and the last crop of broccoli and savoys; sow more lettuce, cabbage-seed, chervil, and corn-salad. If the cauliflowers are backward, plant them on a slight hotbed. Earth up the autumnal cauliflowers; earth up celery and cardoons for blanching, first tying up each plant of the latter by itself with bass. Plant the offsets of eschalots, garlic, and rocambole. Prepare mushroom beds, under a shed, open to the south, if convenient, for the sake of dryness; use fresh stable-dung; and cover the spawn with two inches of earth.

Fruit Garden.—Plant cuttings of gooseberries and currants, to keep up a succesion of young trees, which bear the largest fruit. Plant raspberries and strawberries; the former continue in perfection only about four years, and the latter only two or three years. Nail up fig-trees and vines, and thin the leaves. Guard against insects; the branches of grapes are frequently, for this purpose, put into bags of crape, gauze, or paper; hang nets before valuable fruit, to protect it from birds. Gather ripe fruit in the morning, before the sun becomes hot.

Greenhouse.—If oranges, lemons, and other delicate plants, particularly succulents, have been taken into the open air, for the two last hot months, they should be brought back; but the sashes may be left open all night, if the weather is seasonable. Water sparingly, and cease to water the leaves.

Hothouse.—The gathering of the fruit will be principally finished towards the latter end of this month; and it will be a convenient time for mixing fresh bark with the old, or wholly renewing the bark in the bins, as its state appears to require; as well as for painting, white-washing, and in all respects putting the interior into complete order. The flues should also be swept.

Nursery.—Continue to dig and throw into ridges, the ground designed for planting: transplant seedling trees and shrubs, and propagate by cuttings. Preserve cherry and plum-stones for stocks, and plant the cuttings of apples and pears. Hoe and destroy weeds and vermin every-where. Cuttings should always be planted in moist weather, to spare frequent watering.

TENTH MONTH.—OCTOBER.

Flower Garden and Shrubbery.—Tulips, hyacinths, and other fine bulbous-rooted flowers, designed to blow during the winter, in the hothouse or forcing frames, should now be put into pots; and the bulbous roots designed for the borders, which yet remain out of the ground, would be better planted now than afterwards. Finish the planting of perennials. Put the pots of carnations into hotbeds, and roses into pots for forcing. Make cuttings of the best double chrysanthemums. Prune, transplant, and propagate by cuttings, all kinds of shrubs. Dress the soil for the winter.

Kitchen Garden.—Tie up endive as it is wanted for blanching; earth up cardoons, and the last crop of celery, in dry weather.—Weed the onions, carrots, and winter spinach. Plant out the early cabbages, the last crop of broccoli, and the cauliflowers intended to be covered with glasses. Lettuces may be obtained in winter by covering them with glasses. Cut down the stalks of asparagus, hoe the weeds, throw some earth upon them out of the trench, and cover them with rotten dung. Cut down artichokes, and preserve them from the frost by covering the roots with straw. Sow early pease and beans on a south border, sow cress, mustard, and radishes for small salading. Cut down the flowering stems of aromatic and pot-herbs; hoe them, and spread fresh earth upon the beds. Young mint may be obtained in a month by planting roots of it in a hotbed. Throw vacant ground into ridges, to be ready for any purpose. Finish the planting of mushroom spawn, and cover the beds with straw, as mushrooms grow the most rapidly without light. If the mushroom beds be not under a shed, the straw must be renewed as often as it becomes wet.

Fruit Garden.—Gather all sorts of fruit as it ripens, as soon as the morning dew is gone, if for immediate eating; but not till the middle of the day, if to be preserved for some time. Examine the grapes in bags, as they sometimes become mouldy. Prune and plant all kinds of fruit-trees. The soil of places where fruit-trees are to be placed, should be dug up, and left open for some weeks before the planting is commenced. In wet situations, lay down a cart-load of earth, and plant the tree on the top of a hillock formed with it.

Greenhouse.—Having had the whole interior well cleansed, painted, or white-washed, and put into complete repair for winter, bring in the remainder of the plants, but let the sashes be

always open when the weather is fine. Prune shrubs, and remove dead leaves as fast as they appear. Use but little water.

Hothouse.—If the weather be dry, and the evenings not frosty, fires will scarcely be yet required ; but in case of damp weather, or when the thermometer is below 55 degrees in the morning, fires will be proper. Admit air during the greater part of every fine day. Water very sparingly.

Nursery.—Plant all kinds of forest trees, evergreens, and shrubs. Sow cherry and plum-stones, for stocks.

Eleventh Month.—November.

Flower Garden and Shrubbery.—Protect the seedling bulbs in borders, by straw or a covering of tanner's bark. Bulbous roots may still be planted, but unless it be done early in the month, they will be apt to come up weakly. Finish the planting of flowering shrubs of all sorts, and use fern, litter, or straw, to protect them from frost. Provide the materials of composts for spring use, as marle, loam, sand, bark, dung, &c. Roll grass walks. Several times in a week, remove decayed leaves.

Kitchen Garden.—Tie and earth up cardoons and endive: prick out lettuces, to stand the winter in frames. In dry weather, earth up celery for blanching. Plant beans and pease under a south wall. Earth up broccoli and cabbages. Dig up carrots, parsneps, beets, horse-radish, &c. and lay them in sand out of the reach of frost. Dig up potatoes. Cut down artichokes, and cover them first with soil, and upon that, litter, fern, or straw, to keep the frost from the roots. Weed spinach and spring onions.

Fruit Garden.—Prune gooseberries and currants, and make new plantations of them: prune, and nail up plum, cherry, peach, and other wall-fruits. Plant stone-fruits in open weather; also walnuts and filberts. Gather the remaining fruits; and protect from frost, the roots of peaches, figs, and the delicate kinds of fruit-trees, by litter or straw.

Greenhouse.—Fires will be occasionally required. Admit air as often as the weather will permit, especially if there be much fruit ripening. Clear away decayed leaves, and put fresh earth on the tops of the pots. Water frequently the dry woody plants, and others occasionally. Bring in mignonette, china roses, and other plants which might suffer from the cold.

Hothouse.—Keep the bark beds from fermenting violently, by too much heat; yet fires will be necessary in the evenings, to guard equally against cold and damp. Prune vines, and tie them up. Gentle waterings will be required.

Nursery.—Haws must be gathered and sown in this month at latest. Plant forest-trees and their seeds early in the month. Shelter seedlings and all delicate plants from the frost, by straw, fern, &c. In open weather, vacant ground should be dug and prepared for the spring.

Twelfth Month.—December.

Flower Garden and Shrubbery.—Hyacinths, tulips, anemones, ranunculuses, and other valuable roots in open borders, should be covered with a layer of bark two or three inches deep: bark that has become useless for the hothouse will answer for this purpose. In heavy rains or snow, a covering of mats should be superadded. Auriculas and carnations likewise require protection from heavy rains, and falls of snow. The pots of all plants, which it is not thought necessary to carry into the greenhouse, should be entirely sunk into the earth, as frost will then have the least effect on them. Shrubs in general should be protected by straw, &c. and the more delicate kinds covered with mats, laid over arches formed by hoops. Standing water must be carried off by trenches and drains.

Kitchen Garden.—Occasionally take up the straw from mushroom beds, to prevent mouldiness, and gather the mushrooms which are ready. Sow pease and beans. Earth up celery and cardoous. Cover endive and parsley with straw. Earth up broccoli, boorcole, and cabbages, and pick off their decayed leaves. Cauliflowers and lettuces under glasses should be weeded, and have fresh air in fine weather. Finish the taking up of carrots, parsley, &c. Give air to the asparagus under frames.

Fruit Garden.—Stake newly planted standards which might be displaced by the wind, and protect with furze the trunks of all trees which would be injured by hares or rabbits. Manure the soil where fruit-trees stand. Prune fruit-trees. Examine gathered fruit, and pick out all that is decayed.

Greenhouse.—Keep out the frost and damp by gentle fires. Admit air, in clear mild weather. Remove all decayed leaves. Succulent plants will scarcely require any water, and other plants will require very little.

Hothouse.—Prune vines, and train them in such a manner that they may throw the least shade upon the pines. The heat of the bark should be kept nearly at 90 degrees; the average temperature of the house should be from 65 to 70 degrees. Weed every plant, and remove dead leaves. Fires will generally be required both evening and morning. Water sparingly.

Nursery.—Carry off stagnant water; trim hedges, trench vacant ground, and leave it in ridges for spring. Propagate

trees and shrubs by layers and cuttings, and transplant the hardy sorts. Manure wherever it is required, and form composts for future use.

It may not be superfluous to remark, that the preceding calendar is calculated for the south of England, but by an allowance of a week for every degree further north than London, it will equally answer for any part of the United Kingdom. It must, however, be admitted, that in the same latitude, the warmth or bleakness of particular situations will hasten or retard the times of sowing, and render precautions for the preservation of plants more or less necessary. The variableness of seasons is also a circumstance which cannot be provided against by rule, but the continuance of any particularly unseasonable weather should not be reckoned upon, without the exercise of a considerable share of discretion: thus if mild weather occur during the greater part of March, the following month is still not far enough advanced, to be out of the reach of frost, and care should therefore be taken that if it occur, which in such a season is very likely, the tender plants and blossoms may take no harm; but if a frost of some strength and continuance occur late in April, it may safely be considered, when it breaks up, as the last of the season. In autumn, on the contrary, an early frost, or rough weather, is frequently only the precursor of a late and mild, if not a fine season.

By proper attention to the state of the season, the destructive consequences of blight, which have so generally been considered inevitable, may, there is reason to believe, be often warded off. T. A. Knight observes, that cold weather, particularly cold nights succeeding warm days, is the most extensive source of blights; heat accelerates the motion of the sap to the extremities of trees; exposure to cold, even when temporary, often retards it for some time; hence, if when the blossoms of a fruit-tree are just expanding, a cold night comes on, and the following days are warm, the evaporation from the blossom and leaves exceeds the nourishment supplied, and though the blossom unfold itself, it is unproductive. The best mode of defending wall-trees from this kind of weather is a covering of double and triple net. Standards, which cannot be covered, should be much thinned towards the extremities, so as to admit the light to the centre of the tree, but not a free current of air through. By this mode of pruning, fruit will be found in every part of the tree, except in unfavourable seasons, when the external parts of the tree, having served chiefly as a protection to the internal blossoms, will probably be unfruitful.

DRAWING.

Drawing, strictly speaking, includes only the art of forming the resemblance of objects by means of outlines; but it is usual to call those performances drawings, where only a single colour, as Indian ink, is employed to produce shades.

It is evident that the real merit and utility of a picture is greater in proportion as it more closely resembles the object it is intended to designate; and the test of resemblance is, whether the picture makes the same impression on the eye, as a view of the object itself. The first requisite toward the production of this effect, must undoubtedly be an outline duly proportioned in all its parts to the visible appearance of objects, and this is to be obtained by a knowledge of perspective; the illusion is completed by the proper disposition of colours upon such an outline. Of the art of colouring, but little can be acquired from precepts, but perspective is subject to unalterable rules, and as it communicates the knowledge which is first required, we shall revert to it immediately after noticing the instruments and materials required to be in readiness for the practice of it, and of drawing in general.

Instruments and Materials used in Drawing.

The most usual and convenient material for drawing upon is paper. The kind of paper most proper, except for chalk drawings, is that which the stationers call yellow wove, as the wire-marks which are in the other sort, are an impediment to the point of the pencil. The thickness of paper sold under the name of drawing paper, is usually in proportion to the size of the sheet; but for the smallest drawings it is advisable not to use any paper thinner than that made to the size called *royal*. Some chuse to have their paper hotpressed before they begin to draw upon it; but hotpressed paper does not receive shading so well as the common kind, and the drawing pen is with much greater difficulty made to produce fine and clear strokes upon it. For chalk drawings, the paper is of a brown or grey tint, so that it may easily shew the strokes of black and red chalk. The colour of the paper itself serving for the middle tint, much time is saved.

For the convenience of keeping the paper stretched and smooth, during the progress of the piece, a *drawing-board* is used. A drawing-board is frequently nothing more than a board, planed smooth, and clamped at the edges to prevent its warping; and the paper is fastened down upon it by four or five wafers, or by paste: sometimes the paper is rather larger than the superficies of the board, and being folded down, is pasted to its edge. But the best drawing-boards are those which consist of a frame, for the reception of a moveable pannel, which, when in its place, forms, with the upper surface of the frame, one continued flat surface. The pannel is surrounded by a rebate, which is received by a corresponding projection in the frame; it can therefore always be placed exactly in the same situation, and will remain steady when once fixed. It is fastened by cross bars at the back, and as it is of less thickness than the frame, these bars are of such a thickness, that they do not project above the back of the frame. The edges of the frame should be straight, and formed exactly to right angles. To use this drawing-board, the paper should be a little larger every way than the pannel, suppose about an inch, and the pannel is put into its place with the drawing paper centrally on the face of it, so that the edges of the paper double up into the rebate, and are retained by this doubling, and the tightness of the fitting between the pannel and the frame, without the use of any cement. Drawing-boards should be made of the best mahogany, well seasoned, and the frame should at least be an inch thick. Paper should be damped before it is fitted to a drawing-board, by sponging it with water on the back, that is, on the side which is next the eye, when the paper is held up to the light, and shows the letters of the water mark reversed. After sponging, the paper should be left a few minutes, for the water to sink through, and if it has not become perfectly pliable, it should be sponged again.

The *black-lead pencil* is, for general use, superior to any other implement for tracing outlines. Good pencils of this kind are very scarce. The lead should not be gritty, nor so soft as to crumble away when reduced to a fine point, nor should it be so hard that its marks cannot be erased. It is proper to have pencils of different degrees of hardness; the hardest are fittest for designs drawn with mathematical accuracy; and the softer for free outlines, done entirely by hand and eye. They should be held at a greater distance from the point than a pen, in order to give greater command in moving them in all directions; they should have a fine point, and in forming outlines, the pressure upon them must only be just enough to make them mark. By this means, if the first mark be erroneous, a second may

be drawn at the distance of a hair's breadth from it, and still be a distinct line, by which greater correctness may be obtained than by erasing the false line entirely, and trying again; and a still greater advantage obtained over the common practice of running half a dozen or more lines into one, and guessing, when the pen comes to be used, at the true outline in the midst of them.

Indian-rubber, or *caoutchouc*, is a well-known substance for erasing the lines drawn with the black-lead pencil, or any slight foulness, from the paper. It is sold in square lumps, and in the form of bottles: the latter appears to be of a somewhat different quality to the other, and in general answers better.

Rulers are of two kinds, the *plain ruler* and the *parallel ruler* The plain ruler, which is employed for drawing single or detached lines, is frequently made cylindrical, but a flat one, with at least one bevelled or feather edge, is more steady and certain in use. A Gunter's scale makes a very good plain ruler. A parallel ruler is almost indispensable in all kinds of drawing requiring straight ruled lines; it consists of two straight, flat, plain rulers, united by two bars lying on their upper surfaces: one end of each of these bars turning on a rivet in each ruler, the bars may be separated to a certain extent, but in every position they preserve their parallelism. With this ruler, therefore, if it be required to make a line parallel to one already made, it is only necessary to mark the distance of the two lines at one point; then by setting one of the parallel pieces even with the line, and pressing upon it there, the other parallel piece may be drawn back, and held down in its turn. These alternate movements are performed till the fore edge of the ruler comes to the point through which the line is to pass, when it may be drawn in the usual manner. The saving of time by the use of it is very considerable. The best kind of small rulers sold by the mathematical instrument-makers, are made of ivory; when made of wood, some hard kind should be employed, such as ebony or box; those of ebony are the least liable to warp, but they have the fault of making a mark, if in handling them their edge or corner strike the paper rather forcibly.

A T-square, so called from its resembling the letter T, is used on the drawing-board only, and will supersede the use of the parallel ruler for all lines which are either parallel or at right angles to any side of the board. It consists of a thin flat ruler called the blade, let perpendicularly into the middle of another piece called the stock, which is two or three times its own thickness. The blade being laid on the paper, and the stock brought up close to the edge of the board, it is very readily used in ruling.

Of *compasses* there are several varieties. The common kind are merely for taking distances, or dividing lines; they are there-

fore often called dividers; they should have double joints, one part of which should be steel; and should have hardened steel points. Another pair of compasses should be kept, like the common ones in all respects, except that the lower half or steel part of one limb draws out, and its place is supplied by a steel pen, a dotting point, a crayon point to receive a pencil or crayon, or a long steel limb for drawing large circles, as the case requires. There are also elliptical compasses, for drawing ellipses; triangular compasses, which have three legs, and are of considerable service for taking the position of three points at once; hair-compasses, for taking very small extents with the nicest accuracy; bow-compasses, for drawing very small circles in a ready manner; and proportional compasses, which turn on a centre of which the position is alterable; these are particularly convenient for drawing plans, &c. to different scales. Compasses should have very smooth conical points, to prevent their boring out the paper; when purchased, the points are generally triangular.

Pens.—Common pens, or those made of crow-quills, are frequently employed for inking an outline; but the steel pens, purchased with compasses and other drawing implements of the mathematical instrument-makers, are incomparably superior to any other. Every one who uses them, however, will find the advantage of acquainting himself with the art of keeping them in order. This will require a little attention, but if it be carefully executed, the steel pen will not require a thousandth part of the time, trouble, and even expense, which attends the use of pens made of quills; and its lines will be much more uniform and well defined. The extremities of the steel pieces forming the pen, should be very narrow ellipses, and should perfectly meet, without the least projection of one piece over the other. The outside of the elliptical end should be rubbed on a hone till it is as thin as a knife; in this state the points would cut the paper; but the sharpness must be taken off by gently drawing them separately over the stone upon their edge. This will give their edges a smoothness, to make them glide over the paper, although they will still be left so thin, that their edges singly can scarcely be discerned. By this management, lines may be drawn while the points of the pen are at a distance from each other not perceptibly exceeding the breadth of the lines produced, which is of consequence, not only to the equable flow of so viscid a fluid as Indian ink, but to obtaining a well-defined stroke. The points of the pen should always be so far apart, that the space between them can easily be discerned when they are held up to the light, otherwise they cannot be depended upon for drawing a good

line, and they will be apt to require a degree of pressure, that will wear them very fast. The steel pen is filled with a camel-hair pencil, out of Indian ink rubbed down in pure water: when the ink becomes viscid by the evaporation of part of the water, it should be rejected, and some fresh rubbed out; and ink which has once been rubbed down and become dry, should not again be used for the pen. When the pen appears to be rather clogged, a slip of paper may be drawn between the blades, and in using it, there should be no ink on its external surface. As the mismanagement of the steel pen is extremely common, and the want of a good one is a very fruitful source of vexation, these remarks will not be thought out of place, by those who have the art of drawing yet to learn.

Indian ink.—The real China ink is the best, but is not often procurable. It breaks with a glossy fracture, its lighter shades have rather a brownish hue, and it works perfectly free from grit. The higher the degree in which any ink possesses these qualities, the better it is. Indian ink should be rubbed down with water in little cells made in white marble, and the different shades should be kept distinct. It is of importance to remember that the shading done with this material may be easily darkened, but not made lighter; therefore the learner should not be anxious to produce the full effect at once; and where any shade appears to work up roughly, it may be left altogether for another part of the drawing, till it is dry, and the unevenness of the shade may soon be removed, if no part be too dark.

Of *camel-hair pencils*, with which the shading with Indian ink is performed, scarcely one in a thousand is of a proper shape. The hairs at that part which is next to the extremity of the quill in which they are inserted, should be thicker than the quill itself, and should rapidly terminate in a well-defined point, after being moistened by drawing through the mouth. The whole length of the hairs should very little exceed twice the diameter of the thickest part. When of this shape, the pencil will hold a large quantity of colour, which, from the nearness of the point, will flow there as it is wanted, and will prevent that dryness of touch which is occasioned by a slender narrow pencil. Sable pencils are much stiffer than those of camel's hair, and are always to be preferred for delicate touches, and for making strokes. They are sold at six times the price of the other.

Charcoal is employed for outlines drawn by the eye, as the figures of men and animals. That prepared from the willow is the most esteemed. The strokes made with it are easily rubbed out with a feather.

Chalks.—The chalks used in drawing are black, white, and red. Red chalk is the cheapest, but it is not much used, as it has a dull, unpleasant colour. The white chalk proper for drawing, is harder than common chalk, but the latter will make a substitute for it, if washed fine, mixed up with skimmed milk, and moulded into a proper shape. Pipe clay will also be a tolerable substitute for it, without any preparation. Black chalk is of two kinds, French and Italian; the latter is the harder and more valuable kind of the two. Chalks are used in narrow slips, and are held in a steel or brass case, called a portcrayon. When they are reduced to a point, they are not cut like a black-lead pencil, but in a contrary direction, that is from the point to the upper part. Chalks are much used in copying plaster figures, and drawing after life.

Stumps are small rolls, or cylinders of soft leather or paper, rounded at the ends, and used to soften and blend the shades produced by the strokes made with chalks.

Of Perspective.

Perspective is the art of delineating objects on any given surface, as they would appear to the eye, if that surface were transparent, and the objects themselves were seen through it from a fixed situation.

It often happens that young persons who have gone through a regular course of instruction on drawing, in which perspective has been included, are as completely ignorant of the first principles of the art, as if they had never heard of it. The fact is, that they followed the diagrams before them, or drew lines as they were directed, and having effected their present purpose, they were satisfied, because they were not taught to reflect whether they had derived any principles of general application from what they had done; and their view of the whole subject was indistinct, because they did not perceive the relation between the lines and points which they made for their assistance upon paper, and the unseen path or course of the rays of light in looking at an object itself. This can only be acquired by a knowledge of the principles of optics, the acquisition of which ought to be a preliminary step to the study of perspective, and not left to be derived, as it usually is, from its combination with the rules and practice of perspective. The principles of optics, studied by themselves, are easily understood, and an acquaintance with them will strew flowers in the path of the student's future progress through perspective.

Geometry has been usually specified as a previous and indispensable requisite to the study of perspective; and there can be no question of the correctness of the assertion, where a complete and mathematical investigation of the art is to be undertaken; but the nature of the subject, and of the rules to be followed in ordinary practice, in taking the drawing of a landscape, of a building, or of a machine, may be perfectly comprehended without the scholastic investigation of geometry. It is requisite, for example, to know the names of differently shaped superficies and solids, as circles, triangles, parallelograms, cubes, &c. and of the art of drawing straight and curved lines in any direction upon paper; but the former may be acquired in cases where it is not already known, by the aid of almost any common dictionary, and the latter, to those who are provided with proper instruments, is a mechanical operation, in performing which persons of very humble views experience no difficulty. Thus in drawing, lines perpendicular to other lines are frequently wanted; the geometrical method of obtaining these perpendiculars is very neat and pleasing in its principle, but the mechanical mode of using a square is far more expeditious, as accurate in its effect, and is always the choice of practical men. Upon the whole, the investigation of the nature of different forms, magnitudes, and their relations to each other, which constitute the essence of geometry, and delight the studious mind, may be left unexplored by those who have leisure only for practical studies: although such a knowledge of geometry as may be acquired in a very short time without a teacher, from any elementary work on the subject, is much to be recommended.

Referring the student who is ignorant of the subject, to the essay on optics contained in this work, we will suppose it to be known—that light, by which all objects are rendered visible, consists of particles inconceivably small; that these particles are emitted from luminous bodies, and reflected from all objects on which they fall; that their direction, in a uniform medium, is always in a right line; that the angle of a ray's incidence is always equal to the angle of its reflection; that every ray, when it enters the eye, impresses upon that organ the image of the point from which it issued; that the angle under which any object is seen, when its centre is placed right before that of the eye, and its direction is perpendicular to the axis of the eye, is inversely proportionate to the distance of that object; but that in every other situation, the angle of vision is diminished, not only by the distance at which the object is viewed, but by its obliquity to the axis of the eye; that light is composed of particles of different sorts; and that colours

are supposed to be the consequence of the different magnitudes of the particles of light, and which therefore strike the retina with greater or less force. Of these theorems or propositions, the most important to the elucidation of our present subject, are those which relate to the rectilinear direction of the rays of light; the image these rays form of the object from which they come; and the variableness of the angle of vision, according to the position of any object, or part or line of an object.

To commence with what we hope will be found a very easy way of acquiring a general knowledge of the subject; let the student place himself in a darkened chamber, and there let him make a small hole, not larger than a pea, in the door or window, opposite to some remarkable objects, such as houses or trees, the distance of which should be at least equal to their height, and may with propriety be two or three times that distance; and the experiment will be most agreeably conducted, when the sun shines strongly on the surfaces facing the hole. If a sheet of paper, or any white screen, be placed within the room before the hole, an image of the external objects opposite the aperture, will be depicted upon it. The image will be beautiful, although the outline of the objects will not be very well defined, nor their colours very distinct, for reasons which the study of optics will fully explain. The instruction, however, to be derived from the experiment, will for the present object be the same. It will be observed, that the images of all objects are inverted; and to understand this, the student must be reminded of the rectilinear motion of light. The image on the screen can of course be formed only by those rays of light which enter the chamber at the aperture, and it will be admitted, that the rays from the top of the external objects cannot proceed in a right line to the screen, unless they proceed to the bottom of the screen; therefore, as each ray carries with it the image of the point from which it issued, the top of the objects must be at the bottom of the screen, and the objects on the left hand will be on the right of the image. That the rays of light from the objects cross each other at the aperture, and spread afterwards as they advance, may be proved by varying the distance of the screen; the size of the image upon which, is enlarged by drawing it back, and lessened by placing it nearer the aperture. The student must further be informed, that if he could trace the image on the screen exactly as it is there delineated, he would, on reversing the screen, have an outline of the external objects in accurate perspective. As the proportions of the several parts, therefore, are not altered by the inverted position of the image, they may be contemplated and compared with the original objects,

as if no inversion took place. Suppose the front of a single house to be parallel to the surface of the screen, and its centre very nearly opposite the centre of the aperture, its image upon the screen will be of the same shape as the front itself is known to have, and its dimensions will be obtained by a rule easily discoverable, for the image will be very nearly as much less than the original, as the distance between the image and the aperture, is less than the distance between the original and the aperture. This estimate of the proportion between the image and the object, would not require the qualifying term *nearly*, but would be correct, if the aperture were exactly opposite the centre of the front of the house; but we have supposed the aperture to be nearer one side of the building than the other, in order that the rays from the nearest gable of the house, may pass through the aperture. This being attended to, there will be an image of the gable end upon the screen, and the size and shape of this part of the image must be particularly noticed. It will be found, that though the gable may be in reality as broad as the front, its image is extremely narrow; that its ground line, instead of being level with that of the front, inclines more and more towards the top as it recedes from the eye, and that the further edge of the inclined roof, inclines to this line with a greater degree of inclination than the original is known to have; thus, besides the narrowness in point of breadth, the height of the most distant corner of the gable is in the image shorter than the hithermost corner. This visual contraction of surfaces is called fore-shortening. To understand how it happens, let the student suppose a thread to be stretched from any given point in the most distant angle or vertical edge of the gable, to its image on the screen, or spot on which it would fall by taking a rectilinear course; let another line be supposed to be drawn from an opposite point of the nearest angle of the gable, and it will be perceived that as these lines, like the rays of light, cross at the aperture, they will at the screen form but a very narrow opening, and as the breadth of the image cannot be greater than this opening, the breadth of the gable must be inconsiderable on the screen. It will be obvious at the same time, that the more nearly the gable is taken in front, the greater will be the breadth of its image, while that of the apparent extent of the front will be proportionably contracted. The inclination of the ground line of the gable will be explained, by supposing lines to be drawn from the four corners or limits of the gable to their respective places on the screen; for the line which bounds the further side of the gable, must have a less image on the screen than the hithermost, because it is more distant, and at an

intermediate distance, any vertical line in the gable must have an intermediate height; therefore there must be in the picture, a gradual rising of the ground line towards a point horizontally opposite the place of the aperture:—Now the whole art of perspective consists in observing rules, which teach us to discover the diminutions of all objects seen obliquely like the gable end of the house. To render this experiment and the inferences drawn from it, perfectly clear, it ought to be tried and fully considered. It will then speak to the eye, and the object to be obtained by perspective can scarcely be misunderstood, whereas the impression of mere words is speedily effaced. To prevent any incorrect inference, we shall, however, refer to fig. 1, pl. I, where, let C D represent the window-shutter of the darkened chamber, and *g* the aperture in it; A B an external object, and EF the screen which receives its image. It must be observed, that the darkened chamber is used only as a means of separating the rays which form an image from any other; and that if the direction of the rays could be ascertained as much before the shutter, as they are here behind it, an image of the original object would be obtained, of the same size as that upon the screen, and in its erect position, because the rays have not crossed. Accordingly, in the practice of perspective, the rays of light from an object are always supposed to be intercepted as they converge to the eye at some point, as at *h*, between the original object and the eye. In the experiment, therefore, the aperture in the window-shutter must be considered as representing the pupil of the eye, the darkened chamber, the chamber of the eye, and the screen the retina, or as a means of rendering visible the pictures which the eye receives of visible objects. We need not observe, that a larger aperture, with a convex glass set in it, would in fact form a camera obscura, and a very distinct image would be painted on the screen, at the focus of the glass; but the experiment would then be less simple, and the direction of the rays not so evident. Without a glass, the distinctness of the picture is sufficient to be agreeable, when the eye has been sometime in the chamber.

To consider the foundation of perspective in another point of view, let ABCD, fig. 2, represent a house, seen by the eye at N. The eye N, is supposed to be opposite the corner *q* of the house; its distance from which is equal to N *q*, and its height five feet from the ground. The situation of the eye corresponds to that of the hole in the window-shutter of the former experiment, and the picture of the house formed in the eye itself, corresponds to that which the screen received. In

this situation, as in every other, straight lines drawn from every part of the house to the eye, represent the direction of the rays which form the images of those parts respectively, and thereby render the house visible. The eye, it must be understood, is considered as fixed upon the point *q*, directly before it, and in order that no sensible deviation may be possible, we may suppose it to be looking through a very small aperture in a piece of thin brass *g*. If now a transparent plane, for example a pane of glass, KL, be interposed between the house and the eye, at a short distance from the eye, the whole of the house will be seen through the transparent plane, although the latter is comparatively with the house of very small dimensions, because the rays, in proceeding to their point of convergence at the eye, have approached each other in a proportion inversely as the distance; that is, at half the distance from the object, they only extend over half the space contained between the points of emission; at one-fourth of the distance from the eye, they only take up one-fourth of the space; and the same proportion holds for other distances. Suppose the pane of glass to be within arm's reach of the eye at N, and that it is coated with gum-water or isinglass, so as to receive the marks of a pencil, without having its transparency destroyed: trace the outlines of the house upon the glass, by observing and following exactly the direction in which they are seen through the small aperture in the piece of brass. When this is done, it will be found, that the real or measured extents forming the different external surfaces of the house, are represented by extents modified by the distance and obliquity of these surfaces to the eye—in short, as shewn in the figure, a representation of the house, in true perspective, will be obtained, in the given situation of the eye. To young persons the difficulty of understanding an explanation of this kind, is occasioned by their indistinct perception of the relation between the rays and lines from a real object, and the projection of those lines upon a flat surface, as a sheet of paper. It appears confusing to them to say, that the eye is opposite the corner *q* of the house, and yet to represent it at N, on one side. Unless this difficulty be overcome, and the mind can form a distinct image of the direction which the lines shewn on paper would have if drawn from a real object, perspective diagrams will be contemplated with pain, and the remembrance of them will soon be effaced. We shall therefore propose a little experiment, which we recommend to be tried by those who feel the difficulty alluded to. Let a small model of a house be made of wood, and to every corner of it which can be seen in any one situation, affix a thread of silk,

two or three times as long as the model of the house is high. These threads will represent the rays of light proceeding from the corners ABCD, *f k l m*, of the house in fig. 2, pl. I. Let the threads be drawn through a hole in a piece of thin brass, just large enough to admit them to be moved freely. The hole in the piece of brass will represent the eye. Let small weights be attached to the extremities of the threads which have been passed through the hole in the brass; the threads being thus stretched, will form a right line from the house to the brass, and the apparatus will be ready for elucidating the nature of perspective. While the model of the house remains stationary, let the position of the brass be varied, sometimes placing it higher, sometimes lower, at different distances, and towards different sides, and let the angles formed by the threads in each situation, be attentively considered, by the observer placing himself behind the brass, and supposing himself to regard the house as if he saw it through the hole. Let him, after each remove of the brass, suppose that the threads representing the rays of light, without altering their direction, were to pass through a sheet of paper, interposed at any distance between the brass and the house, and he would find that by drawing lines to join the points thus obtained, an outline representation of the house would be produced, and this representation would be in true perspective. For any one situation, it would not be a troublesome matter to perforate a piece of paper, to be slipped upon the threads without distorting them; and for other situations, a good idea of what the representation would be, or in other words, of the perspective space between any given points, would be obtained by measuring the openings between the threads at equal distances from the brass. After the trial and proper consideration of this experiment, it will be easy to form a tolerably correct idea of the perspective appearance of any object, or assemblage of objects, and not difficult to exhibit that appearance on paper. In perspective diagrams, lines must be drawn to represent the rays, the direction of which, in this experiment, is indicated by threads, and as the view of an object varies with the point from which it is seen, the situation of the eye, both in height and distance, must be laid down upon the paper, on which the perspective drawing of an object is to be made, unless we propose to look at the object itself as through a transparent plane. The question then occurs, how shall the position of the eye be designated on paper?—It can no way be represented so clearly as by placing it on one side, as shewn in fig. 2, or by placing it vertically beneath the object to be drawn, as represented in fig. 5, pl. II.

By whatever means the representation *t u*, fig. 2, pl. I, of an object ABCD, is obtained, if the outline be accurate, and viewed at a proper distance, it is plain it will make an outline of the same form in the eye as the object itself: and if the colouring were equally perfect, the eye might mistake the figure for the original. But even when colours are not employed, correct dimensions give the whole a pleasing appearance, and constitute the first great requisite to every good picture.

Having thus endeavoured to explain the nature of perspective, we may next advert to the limits of vision. We may consider the eye, in whatever direction we look, as situated in the centre of a sphere, which we may suppose to be represented by the circle EKFL. The hemisphere ELF is behind the eye, and therefore obviously invisible; and it is also certain, that the eye, looking forward horizontally to K, cannot take in at once the whole of the hemisphere EKF. So far from this, it cannot take in a larger angle than SRT, which is but half a hemisphere, or equal to 90 degrees. And as the rays which the eye takes in, extend all round to an equal distance from the central ray KR, it follows, that the whole of the rays which enter the eye at once, will be in the form of a cone, of which the apex is at the eye; and of such a cone of rays, SRT may be considered as the profile. It is, however, found, that to have an agreeable view of large objects, such as buildings, the angle of vision should not exceed 60 degrees, or one-third of a hemisphere; in other words, that we cannot distinctly see the whole of any object, unless its distance from the eye be at least equal to its height; and the appearance of a picture will be more agreeable, if not made to comprehend above 45 or at most 50 degrees; indeed, for small objects, or such as do not exceed the length of a foot in any of their dimensions, it is not advisable to exceed an angle of 30 degrees. As a picture, therefore, should never comprise more than the eye can easily take in at one view, a distance of 25 degrees on either side of the point of sight, may be considered a standard limit. Fifty degrees, to the eye at R, are comprehended in the angle *x* R *y*; and we need scarcely observe, that the measure of an angle, is the space it takes up on the circumference of a circle, which has the point of the angle for its centre; a circle being always supposed to contain 360 degrees. Hence, if the lines forming the angle *x* R *y*, were extended, the angle *v* R *t* would still be only one of fifty degrees, because, whatever were the size of a circle drawn from the point R, through its two legs, if that circle were divided into 360 parts, the number of those parts inclosed by the angle could not be more than fifty.

We shall now proceed to the definitions of the terms used in treating of perspective, and then shew the method of putting into perspective, those forms which may be considered as the elements of all others.

Definitions.

1. An *original object*, is any object whatever which is rendered the subject of a picture.

2. *Original planes* or *lines*, are the surfaces or lines of original objects.

3. *Perspective plane*, is the surface on which a picture is delineated.—It may here be observed, that painters regard the frame of a picture merely as an aperture through which original objects are seen; and they therefore consider the perspective plane to be transparent, to admit of this view. It is on this account that the perspective plane is frequently called the *transparent plane*.

4. *Ground plane*, is the earth or surface on which stand the objects to be delineated, as well as the spectator.

5. *Ground line*, is the line on which the perspective plane is supposed to rest.

6. *Visual rays*, are those which, passing through the transparent plane, render original objects visible.

7. *Principal visual ray*, is that which passes through the axis or centre of the eye, and the course of which, therefore, from the perspective plane, is shorter than any other, because it is perfectly direct. Its height above the ground line is of course always the same as that of the eye.

8. *Point of sight*, is that fixed point from which the spectator looks upon the perspective plane, when any original object is delineated.

9. *Centre of the picture*, is that point of the perspective plane which is exactly opposite the point of sight, that is, where the principal visual ray enters the transparent or perspective plane. It must, therefore, be carefully distinguished from the measured centre of any picture, as it can never exceed the height of the eye from the ground line.

10. *The distance of the picture*, or *point of distance*, is the distance between the eye or point of sight, and the centre of the picture.

11. *Vanishing points*, are those points to which all lines inclined to the picture appear to converge, and in which those

lines meet, when produced. Vanishing points have no place in a finished picture; they are used to facilitate drawing in perspective.

12. *The horizontal line*, is a line parallel with the horizon, at the height of the eye, that is, it passes horizontally through the centre of the picture.

13. *Distance of a vanishing point*, is the distance from the vanishing point on the picture to the eye of the spectator.

It may also be proper to remind some, of the difference between a *perpendicular* and a *vertical* line or plane: a vertical line points directly to the centre of the earth; it is therefore at right angles to the plane of the horizon, and is the same with the direction of a plumb-line:—a perpendicular line is any line which is at right angles to another; it may therefore sometimes be a vertical line, sometimes a horizontal one, or in any other position, according to the direction of the line or surface with which it forms a right angle.

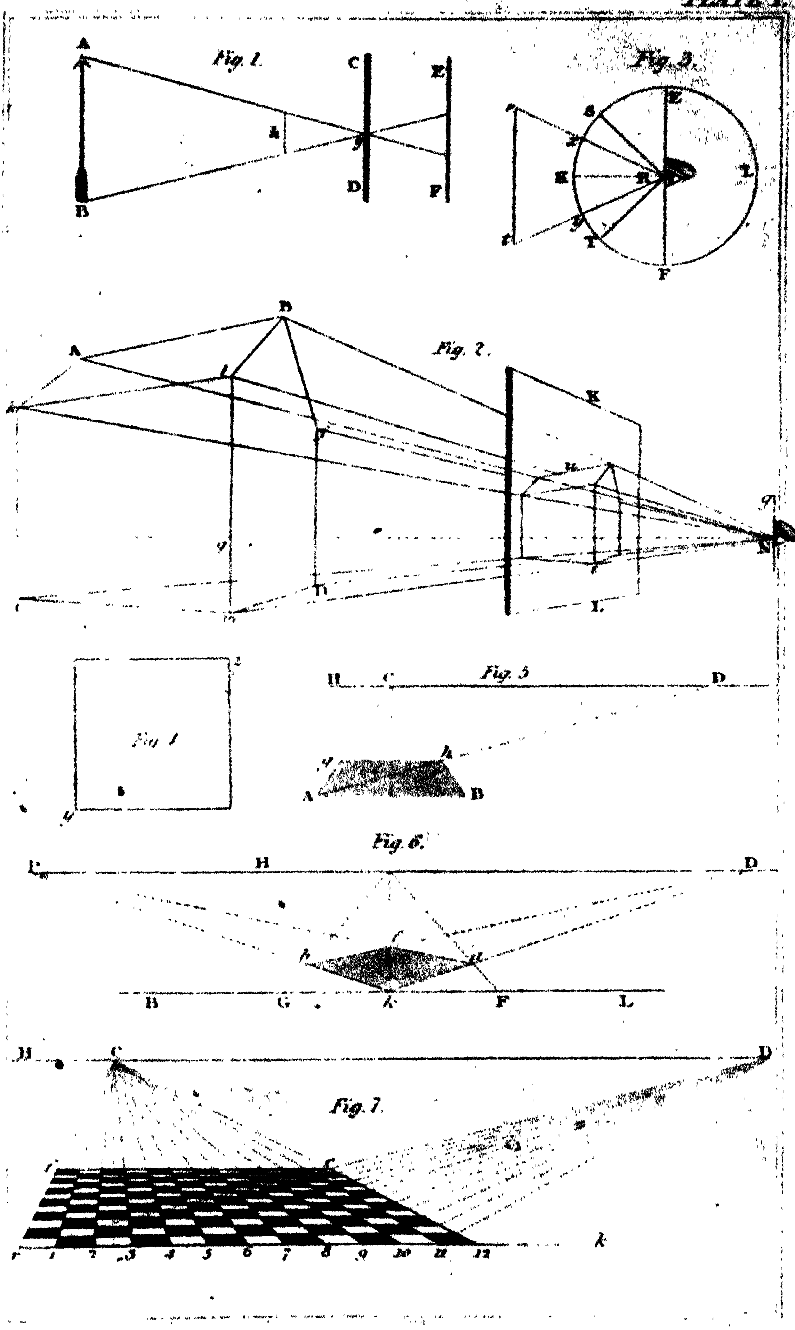
Methods of putting Squares into Perspective.

Suppose a square to be traced upon the ground at some distance before us; that we find upon admeasurement, the length of each side to be eight feet, and that we are opposite the centre of the nearest side, at the distance of eighteen feet. We know that if we wish to obtain what is called a ground plan of this square, we must represent it by a square upon paper, as in fig. 4, pl. I, and thus we shall have its real appearance, supposing the eye to be looking down upon it, just over its centre. But looking upon it obliquely as we have stated, and with the eye at the height of six feet from the ground, we are convinced, from the nature of perspective as before explained, that the side nearest to us will make a longer line upon the retina than any of the rest; the question is, therefore, to obtain the true appearance of the whole square, that is, the true form of the image it makes on the retina. In the first place, determine the scale to be observed, that is, what space shall correspond to a foot of the original; for example, suppose one-tenth of an inch. Then draw a line AB, fig. 5, eight-tenths of an inch long, and another line HD parallel with this base line, at the height of six-tenths of an inch from it. Raise a perpendicular from the centre of the line AB, and the point C, in which it cuts the horizontal line, will be the centre of the picture. From C, on the horizontal line, set off the distance at which the square is seen, which will here be eighteen-tenths of an inch, and the point of distance D, will be obtained. From A, draw the line AC; and from B, the

line BC; then from A, draw the line AD, and to the point *h*, in which AD intersects BC, draw a line *g h*, parallel with the ground line AB; then will A *g* B *h*, form the perspective outline of the square required.

Let it be supposed that the square above described is viewed by an eye situated opposite one of its corners. Draw a base line BL, as before, and on each side of any assumed point *k*, set off half the measured length of the diagonal of the square, viz. half the distance between the corners *y z*, fig. 4. Parallel to the base line, at the height of six-tenths of an inch from it, draw the horizontal line H, and raise from *k*, the perpendicular *k* C. From F draw the line FC, and from G, the line GC. On each side of the centre C, set off on the horizontal line the points of distance PD, and from each of them draw lines to the centre of the base *k*; then from *a*, draw the line *a* P, and from *b*, the line *b* D, and the diagonal view *a b f k*, of the square, will be completed.

We shall give one more example respecting squares: suppose we have a square pavement, composed of equal alternate pieces of black and white marble; the total number of small pieces to be 144, and each of them one foot square. Here there will be six black and six white pieces on each side of the square. Suppose the spectator to stand opposite the middle of the third square on the left, and that for greater clearness the scale be two-tenths of an inch to a foot, with the eye five feet above the ground, but at the distance of eighteen feet as before. Draw a base line *r k*, and divide a part of it into as many equal divisions as there are squares on one side of the original, as, 1, 2, 3, 4, &c. These divisions, by the scale now adopted, will each be two-tenths of an inch. Draw the horizontal line at the distance of five feet (according to the scale) from the base. From the middle of the space between 2 and 3, raise a perpendicular, and to the point C, in which it cuts the horizontal line, draw lines from the commencement and the termination of the divisions on the ground line, viz. *r* C, and 12 C. From C, set off the distance CD, eighteen feet, for the distance of the eye. Draw the line *r* D, and from *e*, where it intersects the line 12 C, draw a line *e f*, parallel with the base line *r k*; then will *r f e* 12, give the boundaries of the pavement. To obtain the reticulations, draw lines from each of the divisions, 1, 2, 3, &c. on the base line, to the centre of the picture C, and from each of the same divisions to the point of distance D. The lines drawn from the divisions to C, form the right and left sides of the small squares, and the lines drawn from the divisions to D, give the points on the line C 12, from which the horizontal lines may be drawn to form the other sides of the squares



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Or, after all the lines are drawn from the divisions on the ground line to the centre C, and also the line *r* D, the remaining sides of the squares may be obtained by drawing parallel lines through the various points in which the part *r e*, of the line *r* D, intersects the lines drawn to the centre C.

It is often thought, by those who are commencing this study, that representations such as the one now given, have no resemblance to the originals; but if they be examined as every picture ought to be examined, opposite the point of sight, and at the distance for which they are drawn, the idea of their incorrectness will disappear: to render the illusion the more complete, the figure should be viewed through a small tube or aperture, to prevent the intrusion of surrounding objects. It must also be observed, that diagrams upon paper have frequently, for the sake of convenience, a vanishing point so near, that the eye has not the power of distinct vision at the distance for which they are drawn. Such designs, therefore, although correct in principle, will not appear correct to the eye unless enlarged.

To put a Circle into Perspective.

The perspective or oblique view of a circle is an ellipse, and it is usually obtained by drawing a square of a size just sufficient to contain the circle, and dividing it into small squares, then putting the divided square into perspective, and drawing within it a line through the corresponding parts of the small squares, and this line will be an ellipse. Thus, to obtain the perspective of a circle EFGH, fig. 1, pl. II, draw round it the square ABCD. Divide the square into small squares, the number of which should be increased in proportion to the exactness with which the perspective curve must be obtained: draw also the diagonals, CB and AD. Throw the square and reticulations into perspective, as represented in fig. 2, where C is the centre of the picture, and D the point of distance; then draw the curve by hand through the parts corresponding to those through which the circle passes in fig. 1. The perspective view of a circle will be an ellipse, whether the square is viewed opposite the middle of one of its sides, as in fig. 2; or even with one of its angles, as in fig. 3, where BC is the line of sight; or at a distance on one side, as in fig. 4, where LC is the line of sight. The point of distance, in figs. 3 and 4, is the same as in fig. 2, though in fig. 4 it could not be drawn without extending beyond the limits of the plate.

To put a Triangular Prism into Perspective.

To represent in perspective a triangular prism or solid, standing vertically upon one of its ends, and viewed by an eye just opposite one of its angles; draw by admeasurement a plan of the prism, as *a b c*, fig. 5, pl. II. then draw the line GK, across the outermost boundary of the triangle, and make EF parallel with GK. From *e* let fall the line *e d*, perpendicular to GK. On *c d*, set off the measured distance of the eye from the prism, and mark the place of the eye as at *d*. From *a* and *b*, draw lines meeting each other in *d*. From *d*, draw the line *d m*, parallel with *a c* of the triangle, and on the other side the line *d l*, parallel with *b c*. From *e* raise the perpendicular *e f* to the measured height of the nearest angle of the prism to which the eye is opposite. On *e f*, measure the height of the eye from the ground line GK, and draw the horizontal line HH. Take the distance *c m*, set it off on each side from *n*, and it will give the vanishing points VP and V. Draw the lines *e* VP and *e* V. Then from *o* and *p*, where the lines from *a* and *b*, in proceeding to the eye, cut the line EF, draw the lines *p q* and *o s*, parallel with *e f*. Draw the lines V *x f*, and *f w* VP, and the perspective outlines, *w f x r e z*, of the prism, whose base is equal to the triangle *a b c*, will be obtained, and may be finished by shading it according to the direction in which the light falls upon it. This mode of drawing from a ground plan is extremely useful, and well calculated to shew the difference between the visual and real dimensions of objects. The outlines of the house ABCD, in fig. 2, pl. I, were obtained by it: it should be rendered familiar by frequent practice on figures in different positions.

To put a Cube and a Cylinder into Perspective.

As the base of a cube is a square, it may, when viewed as in the present example, opposite one of its angles, be put into perspective by the same process as the square in fig. 6, pl. I, and figs. 2, 3, and 4, pl. II, will explain the manner in which the perspective of a square, seen in other positions, may be obtained. Having then obtained the base, we shall find that when H is the horizontal line, PD the points of distance, and *a b* half the measured length of the diagonal of the cube, the perspective of the base will be represented by *a f d g*. Make the height of *a e* equal to the measured length, according to the scale, of one of the sides of the cube, then draw the lines *e* D and *e* P. From *f* and *g*, draw lines parallel with *a e*, for the sides of the figure: draw the line *e* F to a perpendicular let

fall from the horizontal line at P to M. From F draw a line to any part of the horizontal line, as to L, and draw from M a line to met this in L. To *f* draw the line *f h*, and to *d* the line *i d*; then from *h* and *i*, raise perpendiculars to intersect FL, and from the points of intersection draw the lines *p l* and *r k*: thus will be obtained the perspective outline of the cube *k l f a g o e*. If the cube had not been viewed directly opposite one of its angles, the points of distance would not on each side have coincided with the vanishing points; and the vanishing points would have been best obtained as for the triangular prism, fig. 5.

The procedure for a parallelopiped is essentially the same as for a cube. To put a cylinder into perspective, first proceed as for a cube, or parallelopiped; draw on the perspective of each end such an ellipse as it will admit; let the longer or conjugate axes be equal, and join the opposite extremities of these axes by two parallel lines, as shewn in fig. 7. Having thus obtained the perspective of the cylinder, it only remains to erase the lines which belong to the cube or parallelopiped.

Of Shadows, and Description of a Machine for drawing in Perspective.

Having now shewn the mode of putting into perspective those elementary forms which enter into the composition of drawings of every description, we shall be obliged to be concise with the remainder of the subject. The student must be aware, how much difference of position affects the visual appearance of objects, and that by a proper attention to this circumstance, the few rules which have been given may be applied to subjects of considerable complication. To acquire a knowledge of the principles of perspective, it is recommended not merely to compare the plates with the printed page; but to copy the diagrams, and for the sake of greater perspicuity, to do this on as large a scale as may be convenient. Afterwards, some treatise especially devoted to the subject may be perused, and perhaps Brook Taylor's and Malton's may be the best; though these authors will require considerable attention, they have the merit of being sure guides.

With respect to shadows, the proper distribution of which give such life to perspective drawings, it may be useful to remark, that the shadow cast by any object, covers the precise space which that object would prevent the eye from seeing, if the eye were in the place of the luminous body. The position, therefore, of the luminous body, must always be ascertained, and the shadow to be assigned to any object in a picture, will

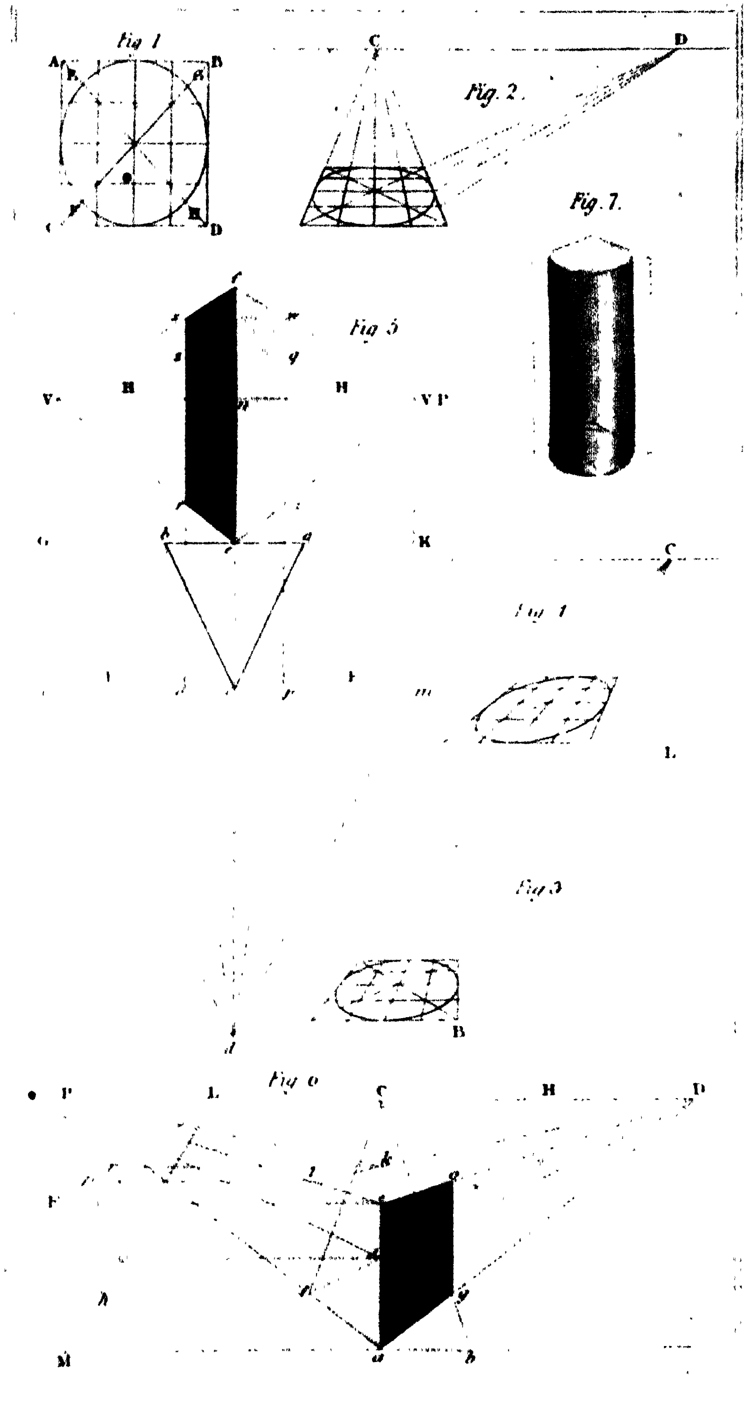
be a perspective view of the space which the eye would be prevented from seeing if in the place of the luminous body. A few experiments with a candle at night will be an easy mode of gaining a little acquaintance with this subject; it must, however, be observed, that the shadow from a candle is every way larger than that part of the object which intercepts the rays; but in point of breadth, this never happens with the shadows of the sun. The reason is, that the rays from the candle considerably diverge, while those from the sun, on account of the immense distance of that luminary, have no perceptible deviation from parallelism. It must be remembered also, that strong reflections from surrounding objects will diminish the intensity of shades; and that not only the quantity of light which falls on an object, but the quantity which can be reflected to the eye, must be considered.

As it frequently happens that persons have occasion to draw in perspective, who have acquired no theoretical knowledge of the art, for the use of such, a great variety of machines have been constructed. Most of these machines are on optical principles; the camera obscura, which we have already described, is one of them; and the camera lucida is another. In praise of the latter, much has lately been said; but although it must be admitted to be a very portable and beautiful instrument, the acquisition of the proper art of using it, is extremely difficult to all, and to some impossible. Its chief use will be that of affording the means of contemplating the real perspective appearance of objects, and perhaps to obtain the position of a few points, but for very minute delineation it is of little value. For general use, we may venture to recommend an instrument described by Ferguson, to whom the knowledge of it was communicated by Dr. Bevis. It has the advantage of other machines in two points: it may be constructed at a small expense by any tolerably skilful artisan in wood, and the use of it will constantly tend to render the practice of perspective drawing more easy, by the manner in which it produces the measure of surfaces or angles. It will therefore, better than most other instruments for the same purpose, supply the want of a more extended essay.

The machine in question is represented at figs. 1 and 2, pl. III. Fig. 1 is a plan, and fig. 2 a view of it on a larger scale. The same letters refer to the corresponding parts in both figures. ABEF is an oblong board, and XY are two hinges, on which the part CLD is moveable. This part consists of two arches, or portions of arches, CML, and DNL, joined together at the top L, and at the bottom to the cross bar DC, to which one part of each hinge is fixed, and the other part

DRAWING.

PLATE II.



to a flat board, half the length of the board ABEF, and glued to its uppermost side. The centre of the arch CML is at D, and the centre of the arch DNL is at C.

On the outer side of the arch DNL is a sliding piece N, (much like the nut of the quadrant of altitude belonging to a common globe,) which may be moved to any part of the arch between D and L; and there is such another slider O, on the arch CML, which may be set to any part between C and L. A thread CPN is stretched tight from the centre C to the slider N, and such another thread is stretched from the centre D to the slider O; the ends of the threads being fastened to these centres and sliders. It is plain, therefore, that by moving the sliders on their respective arches, the intersection P of the threads may be brought to any point of the open space within those arches.

In the groove K, is a straight sliding bar I, which may be drawn further out, or pushed further in, at pleasure. To the outer end of this bar I, fig. 2, is fixed the upright piece HZ, in which is a groove for receiving the sliding piece Q. In this slider is a small hole R, for the eye to look through in using the machine; and there is a long slit in HZ, to let the hole R be seen through when the eye is placed behind it, at any height of the hole above the level of the bar I.

Suppose a house, *q s r p*, to be at a considerable distance beyond the limits of the plate, to obtain a perspective representation of it, place the machine on a table, with the end EF, of the horizontal board ABEF towards the house, so that, when the arch DLC is set upright, the middle part of the open space, (about P) within it, may be even with the house when the eye is placed at Z, and looking at the house through the small hole R; and then fix the corners of a square piece of paper with four wafers, on the surface of that half of the horizontal board which is nearest the house.

To complete the arrangement of the apparatus for drawing, set the arch upright, as in the figure, which it will be when it comes to the perpendicular side T, of the upright piece ST, fixed to the horizontal board behind D. Then placing the eye at Z, look through the hole R at any point of the house, as *q*, and move the sliders N and O, till the intersection of the threads at P, is directly between the eye and the point *q*; then put down the arch flat upon the paper on the board, as at *s t*, and the intersection of the threads will be at W. Mark the point W on the paper with the dot of a black-lead pencil, and set the arch upright again as before: then look through the hole R, and move the sliders N and O till the intersection of the threads

comes between the eye and any other point of the house, as *w*; this being done, put down the arch again to the paper, and make a pencil-mark thereon at the intersection of the thread as before; obtain the point *p* in the same manner, and draw a line from that mark to the one at *w*. The line *p w*, thus obtained, will be a representation, in true perspective, of the corner *p q* of the house.

By thus bringing the intersection of the threads successively between the eye and other points of the outlines of the house, as *r s*, &c. and putting down the arch to mark the corresponding points on the paper, at the intersection of the threads, then connecting these points by straight lines, the entire perspective outline of the house will be obtained. In like manner, find points for the corners of the doors, windows, &c. and draw the finishing lines from point to point. The perspective drawing thus produced, may then be completed, by shading it according to the manner in which the light is observed to fall on the original.

Great care must be taken, during the whole of the time, that the position of the machine be not shifted on the table; and to prevent such an accident, the table or support employed should be perfectly steady, and the machine fixed down upon it by screws or clamps.

It is obvious, that a landscape, or any number of objects within the field of view through the arch, may be delineated, by finding a sufficient number of points, and connecting them by straight or curved lines, as they appear in the original objects.

The arch ought to be not less than a foot wide at the bottom, that the eye at Z may have a large field of view through it; and the eye should be then, at least, ten inches and a half from the intersection of the threads at P, when the arch is set upright. If the eye be nearer, the boundaries of the view, at the sides near the foot of the arch, will subtend an angle at Z of more than 60 degrees, which will not only strain the eye, but will cause the outermost parts of the drawing to have a disagreeable appearance.—To avoid this, it will be proper to draw back the sliding bar I, till Z be fourteen inches and a half distant from P; and then the whole field of view through the foot-wide arch, will not subtend an angle to the eye at Z of more than 45 degrees; which will give a more easy and pleasant view, not only of the objects themselves, but of their representations upon the paper on which they are delineated. Hence, whatever may be the width of the arch, the distance of the

eye from it should be in this proportion: as 12 is to the width of the arch, so is 14½ to the distance of the eye (at Z) from it.

If a pane of glass, previously coated with thin gum-water, and dried, be fixed in the arch, a person who looks through the hole at R, may delineate upon the glass, the objects which he sees at a distance, and the delineation may be afterwards transferred to paper. By this means will be saved the trouble of putting down the arch, to take the position of every point, but it will not be so easy to obtain a correct representation.

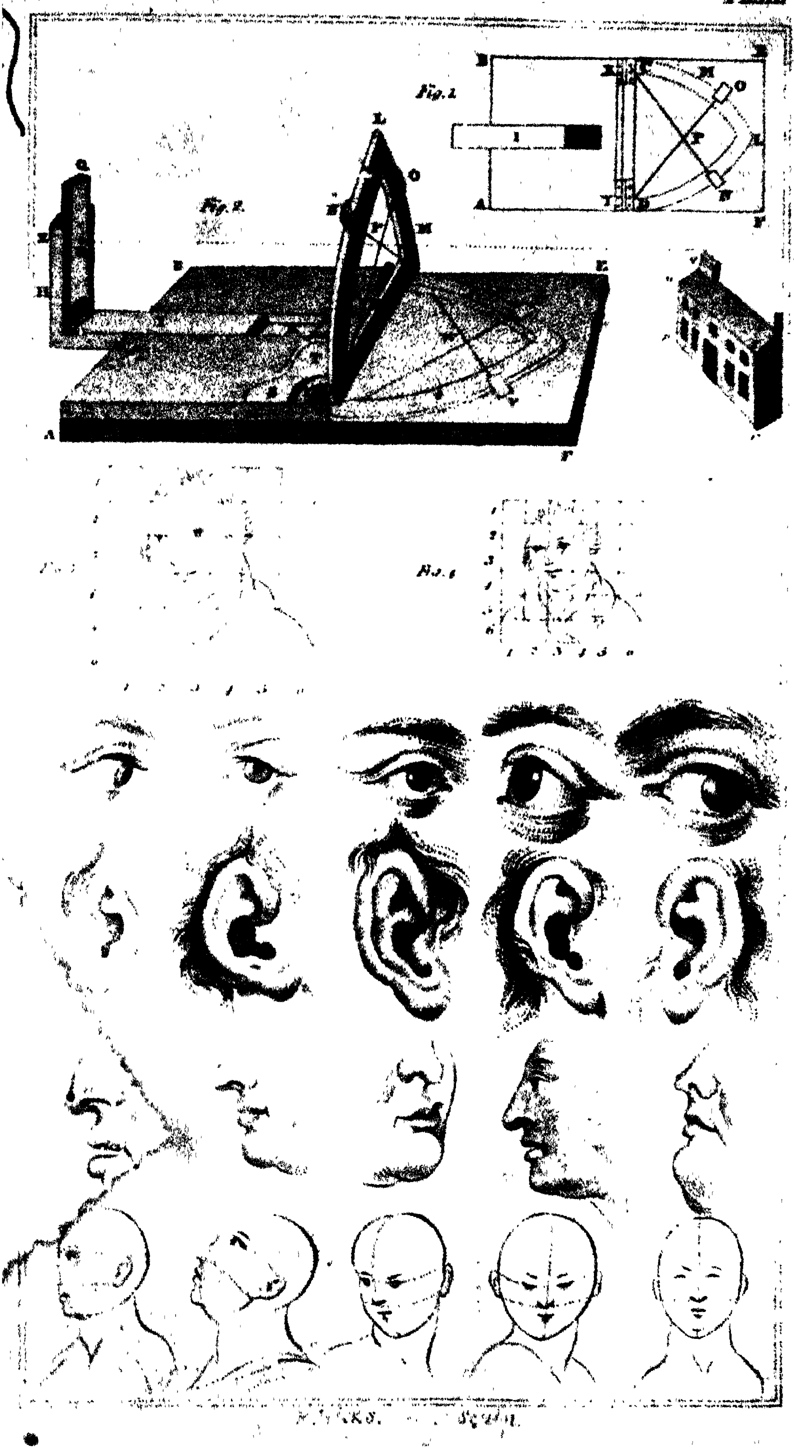
Of Drawing the Human Figure, and Animals.

The first attempts of those who learn to draw, should be confined to subjects of extreme simplicity. The drawing of strokes by the eye with the black-lead pencil, charcoal, or chalk, will afford the most proper exercise. A facility ought to be required of forming them in every possible direction and form; straight, curved, parallel, equidistant, of equal and unequal thickness, upwards, downwards, and across the surface drawn upon. By lessons of this kind, command of pencil is acquired more easily, and in a shorter time, than by engaging at first with complete subjects; nor should the learner be satisfied, till he can correctly produce every description of line at once, and is able to measure distances by his eye with considerable correctness. Those who readily give way to the practice of erasing lines, or retouching them, can scarcely avoid relying on these assistances to an excess which retards their future progress.

When the student can use the pencil with freedom and correctness in drawing lines of every sort, he may proceed to the outlines of eyes, ears, feet, arms, hands, and other detached parts of the human body, copying from drawings, or from prints, where drawings cannot be obtained. But from his commencement to his last step, he should copy nothing which he cannot ascertain to be executed in a good style: as a familiarity with meanness will certainly cramp his genius and debase his style. He should also sketch with a light hand, to make retouching more easy, and the effect more distinct, and nothing should be finished with haste. The next step will be the drawing of the face, with the same care and attention, and combining at the same time the study of the proportion of its parts, as the knowledge of these will render the work more easy. The head is usually divided into four equal parts. 1. From the crown of the head to the top of the forehead.

2. From the top of the forehead to the eyebrows. 3. From the eyebrows to the bottom of the nose. 4. From the bottom of the nose to the bottom of the chin. These proportions may be somewhat deviated from, and the countenance still be a fine one; but for ideal figures of beauty, they may be considered as correct. The usual direction for learning to draw faces, is, to draw a complete oval, and to make a line perpendicularly down the middle of it. Through the middle of this line draw a line across the oval from one side to the other. On these two lines the features of the face are disposed as follows: Divide the line passing through the longer diameter of the oval into four equal parts: allot the first to the hair of the head; the second is from the top of the forehead to the nose between the eyebrows; the third is from thence to the bottom of the nose; and the fourth includes the lips and chin. The transverse line, or breadth of the face, is always supposed to be the length of five eyes; divide it therefore into five equal parts, and place the eyes upon it so as to leave exactly the breadth of one eye between them for a front view; in other positions the distance will be less in proportion as one eye is turned away. The top of the ear is to rise parallel to the eyebrows, at the end of the transverse line; and the bottom of it must be even with the bottom of the nose. The nostrils ought not to come out further than the corner of the eye in any face; and the middle of the mouth must always be placed upon the perpendicular line. The practice of drawing the head, as well as all other parts of the body, should extend to every variety of natural position, and it is advisable, in all the early lessons, to draw upon a large scale. See plates III. and IV.

In drawing a full length figure, it is also necessary to be aware of the natural proportions and relations of the several parts to each other. The human figure is usually divided into eight or ten equal parts; and in drawing it, these divisions are marked, or supposed to be marked, on a line passing down the middle of the figure when in an upright position. In the eight-fold division, the head occupies the first division, and therefore the whole figure is said to be divided into heads. In the tenfold division, which is called dividing the figure by faces, the first division extends from the crown of the head to the under lip, and proceeding downwards, the seventh division falls exactly on the bend of the knee; and from thence to the bottom of the heel takes up the remaining three. The height of a well-proportioned figure, is equal to the extent between the tips of the middle fingers, when the arms and hands are fully stretched out in a line. The breadth of the body, from


Fig. 1
Fig. 2



shoulder to shoulder, is equal to two heads. From the crown of the head to the forehead, is the third part of a face. The face begins at the roots of the lowest hairs on the forehead, and ends at the bottom of the chin. The face is divided into three proportional parts; the first contains the forehead, the second the nose, and the third the mouth and chin. From the chin to the pit between the collar-bones is twice the length of the nose; thence to the lowest part of the breast, one face; from the lowest part of the breast to the navel, one face; thence to the groin, one face; to the upper part of the knee, two; the knee, half a face. From the lower part of the knee to the ancle, two faces; from the ancle to the sole of the foot, half a face. The bone of the arm, from the shoulder to the elbow, two faces. From the elbow to the root of the little finger, is two faces. From the shoulder-blade to the hollow between the collar-bones, one face. The sole of the foot is the sixth part of the figure. The hand is the length of the face. The thumb is the length of the nose, and the length of the great toe is the same. The breadths of the limbs cannot be in the same manner reduced to a standard, as they vary materially with the habits of individuals. The most finished models of the human figure existing, are those left us by the ancient Greeks; and these, or correct drawings or casts of them, should, with the anatomy of the muscles, be carefully studied.

The human figure is bounded entirely by curved surfaces; in sketching or shading it, therefore, straight lines must never appear; it is by the happy intermixture of the curves in different directions, that truth of representation must be produced. In drawing the figure, begin with the head first, and the other parts in succession, sketching slightly before any part is finished, and the right side of the figure should be drawn first, in order that the hand may not cover any part of what is done.

In copying the human figure from the life, the eye of the artist should be at the same height as that of the subject.

To those who wish to draw after life, the human figure affords the most instructive and interesting subject that the pencil can have. The character of different animals may be obtained with much more facility, but still, for those of the larger and more noble kinds, it is best to proceed by learning to draw their several parts correctly. Some make the drawing of animals a preliminary study to that of the human figure, and this perhaps may be most proper when the pupil is young, as it is easy to obtain a certain merit of resemblance, which invites to perseverance. In drawing birds, the smallest feathers

are about the head, and proceed in ranges gradually increasing in size to the tail. In drawing all birds and quadrupeds, their outline should be completed first, and where they form the object of the piece, they should have a back-ground of such scenery as they naturally inhabit.

Of Drawing Landscapes.

To most of those who practise drawing for recreation, landscape-drawing is the most attractive and frequent exercise. The principles of perspective, so far as respects the diminution of surfaces by obliquity and distance, governs every kind of drawing; in drawing from animated nature, however, there is little scope for shewing its importance; but to buildings, extensive views of countries, and other most usual objects of landscape-painting, its principles have so direct an application, that the previous acquisition of it becomes almost the only sure handmaid to success. Habituated to the precepts and practice of perspective, the eye becomes more accurate, and requires but little assistance in taking the just proportions of objects in a landscape.

In order to facilitate the visual measurement of objects, it may be useful, in copying drawings or prints, to suppose the original divided into squares, and the copy in like manner: or at least to suppose, in the original and copy, a horizontal line, and a perpendicular crossing its centre; then to make the copy correspond to the original in all its parts with respect to these lines. It is also proper to observe, that when any design is copied, it should never be allowed to lie horizontally on the table upon which the artist is employed; be cause he cannot, in that position, correctly estimate its proportions. It should be set up vertically, so that its point of sight may be directly opposed to the eye, and its distance equal to that for which it is drawn.

In drawing a landscape from nature, a position on rising ground should generally be preferred, provided it commands an equally pleasing view of the objects to be delineated as a different situation. Divide the space designed for the piece, into three parts, and suppose the original scene to be divided in like manner. Then draw that part of the landscape first, which belongs to the central division of the picture, after which, by turning the head, but not the body, draw the sub jects on the right and left, and connect them justly with it.

It is true, that nothing, according to the principles of perspective, ought to be comprised in a picture, but what the eye

can take in at once; and the direction just given for moving the eye, is not intended to oppose this principle. It arises from a circumstance of which any person may convince himself; although the eye will take in a very large landscape, and the whole of it appears distinct, yet it is only the involuntary and rapid facility of turning the eye to each part that renders it so; what the eye sees *distinctly* at once, is comparatively but a speck in the vast scene; and therefore it must necessarily turn to different parts, or they could not be seen with the distinctness necessary to draw them, although the same effect only must be produced as if they were viewed from a fixed point.

The lights and shades of the landscape must all fall one way; the effect of wind must also appear in one direction, and its effects must be every where proportionate to each other: the surface of the water must be ruffled; and the small boughs of trees must show more of its effects than the larger; in places also situated near the sea, it will be observed that the trees usually lean from it.

In no part of a landscape should the lines have the appearance of having been drawn by a ruler, although a ruler may have been used in drawing some of the outlines. To avoid this, and to give the appearance of freedom to the whole piece, a pen should never follow the black-lead, but the hair-pencil only. If the student have allowed himself to daub with the lead any part intended to be left nearly white, he had better take out that part, and make a single good line. When the lines are drawn with sufficient delicacy, they all disappear under the use of the camel-hair pencil, and the piece has a softness correspondent to nature, and always observable in a camera obscura.

The characters of the trees introduced into the piece, should be carefully studied, and accurately expressed; which can only be done by a real knowledge of their mode of growth, with respect to their contour, disposition of their branches, the smoothness or roughness of their trunks, the darkness or lightness of their verdure, and the clustering of their leaves; always remembering, that as the largest leaves cannot be distinctly seen at the distance of a few yards, they must never, when at the distance perhaps of miles, appear as if they had been counted. The fertility of climate in which the landscape is taken, the season of the year, and the time of the day, will all contribute to diversify the appearances which must be noticed.

The finest picture of inanimate nature appears dull and cold, without some assistance from the presence of living objects, as groups of cattle, or other animals, or human beings.

Of Drawing Flowers.

In drawing flowers, the centre should be drawn first, as by spreading outwards, the graceful and ever-varying forms of nature, in every stem and leaf, may be more easily expressed. In the subsequent operation of colouring them, they require much more attention than landscapes, to produce a soft and accurate effect; but not an equal degree of skill and experience to produce a beautiful whole. All stiffness of outline must be sedulously avoided; the tints laid on extremely thin, and the purity of the colours preserved as much as possible, by a distinct pencil for each of them. In this kind of drawing, as in every other, the first lessons should be obtained by following the draughts of the most skilful masters, comparing their productions at the same time with nature. As flower-pieces are inspected with almost microscopic attention, the fibres and figure of every leaf must be distinctly expressed.—Flowers which do not blow at the same season of the year, should never be grouped together.

Of Light and Shade.

It is by a proper distribution of light and shade upon a correct outline, that the eye receives from a plain surface the idea of solid substances, or substantial forms, together with their relative distances, and true situation. The first point is, to consider in what direction the light falls upon the objects drawn, and all shadows must of course fall one way, and from the light. That part of the piece which is nearest the quarter from which the light comes, must be the brightest, and the remainder must be gradually darkened. Surfaces which project, being nearer the light than others, must be sharp and well illumined, where the enlightened side can be seen. The faintest part of the picture should be put in first, proceeding gradually to the darkest. All the shades should be rather too light at first, that they may be worked up gradually to the full effect. All strong lights must be relieved by deep shades; but it must be remembered, that strong reflections diminish, and always soften, the shades cast by the original light, so as in some instances to make the side of a body which retires from the light, brighter than a nearer part. It is by the reflection of light received from the sky, or terrestrial surfaces, that the darkest part of cylindrical and globular bodies is not that which is the most distant from the original light; and from

the peculiar nature of the reflection from such surfaces, when the light falls on one side of them, the lightest part is not always that which is nearest the light. In shading an upright round pillar, for example, a small portion of the side nearest the light, supposing the light to come from one side, should be a little shaded, the next portion should exhibit the strongest light, which in water colours will be the colour of the paper left untouched; then will come the deepest shade, and lastly a shade for the further side somewhat deeper than the one on the side nearest the light. These shades, imperceptibly blending with each other, will give the idea of a round body. Titian declared that the best lessons he ever received on the distribution of light and shade, were derived from studying and drawing bunches of grapes.

In judging of the merit of their paintings, painters frequently make use of a mirror, in which their piece ought to have the same appearance as the objects it is meant to represent, supposed to be seen at the same distance.

Aged countenances require more shade than those of young people, because they are rugged and wrinkled, and the whole complexion is darker. The hair of the head requires much shade, because, from its numerous interstices, a large portion of the light it receives is lost; and the same remark applies to foliage, and similar objects. The smooth surface of a stone building, is much relieved by the shades of the windows, and of mouldings, as also by marking the joints of the masonry. In a near view, there will be a difference in the shade of different pieces of stone.

The silvery brightness of water is difficult to produce, and requires the fullest light, with a strong contrast from surrounding objects. Foam and waves require an intermixture of strong light and shade, which renders them more easy.

In shading clouds, those at the top of the piece, which are nearest the eye, are to be made the darkest, gradually making them lighter and more faint towards the horizon.

•The outlines of those parts of objects, which are strongly illumined, must be small and faint; while the outlines of those parts which are in the shade, must be broad and full. Outlines must also be further modified by the distance of objects, in order that the haziness, indistinctness, and total loss of particular lines, which distance occasions, may be exactly imitated.

Shadows ought rarely to be terminated by well-defined lines, but should be softened at the edges, and mingled in some degree with the ground or surrounding light: this effect should be more fully produced, as the distance of the shadow from the body which occasions it increases. The greater the

distance also of bodies from the eye, the more indistinct must their shadows be.

The proportion of light and shade, which the practice of the most eminent artists has most frequently sanctioned, is one part of deep shadow, one part resplendent, and two parts half shadow or middle tint. But to produce a fine effect, there should always be some principal mass of light, which should seldom be in the middle of the piece, because it would there in most subjects have too much the appearance of artifice; nor should it be entirely on one side, because part of its effect would be lost by the want of a surrounding shadow. In general, the strongest and principal mass of light should be placed near the middle of the piece, the deep shadow near it, and a large proportion of the middle tint at the extremities on either side. Sir Joshua Reynolds, in his travels, when he observed any fine paintings, remarkable for their chiaro-oscuro, (the Italian words for the light and shade of pictures,) copied, without any regard to the subject or the drawing of the figures, the gradations of shade, and left the paper white for the strong lights. By these experiments he generally found the proportion of light and shade to be nearly what we have stated, and that such a blotted paper, when viewed from a suitable distance, had something excellent in it, although nothing could be discerned of the nature of the subject, or of any definite figures.

Of Drapery.

The judicious execution of drapery requires the strictest attention to the form of the body which it covers, and to the texture of the cloth itself. Some artists, to prevent draperies from misleading them, draw their figures without drapery, and then clothe them. The principal folds are to be drawn first. The finer the stuff, the more numerous and the smaller its folds must be made. The more remote any part of the drapery is from the place of constraint, the more perfectly it will have returned to a straight hanging position; and the smaller and the more numerous the folds, the sooner they will terminate. The drapery should never appear to keep the person under any kind of constraint, and those deep shadows, which would appear to the eye like hollows which penetrate the limb, must carefully be avoided. Where a figure, or any part of it, is fore-shortened, the drapery must appear more tumefied, and in more numerous circular folds, than in the same limb at length. If the figure be in motion, the loose parts of the drapery will, according to the degree of that motion, be more or less inclined, in a direction contrary to the motion,

as if it were impelled by wind. Persons of rank should have ample and rich draperies; those of ladies and nymphs, should be characterized by lightness and softness; peasants and beggars have short, coarse draperies. Folds consist of two shades, and no more, the inner side being shaded the deepest. An attention to the correct display of draperies, will show the impropriety of excessive masses of black, as a black garment must be shaded by black. The shades in silk and fine linen, are thick, small, and soft, and they require a light shadow.

Painters who have much occasion to draw draperies, frequently provide themselves with a figure called a layman, which is made of wood, and jointed in such a manner that it may be placed in almost any position the human body can assume. When this figure is clothed with the drapery required, and set in the position to be depicted, it affords the painter an opportunity of studying the drapery at his leisure, of which the living subject would not admit. Assistance may certainly be derived from the use of a layman, but if the painter relies upon it generally, instead of endeavouring to fix the fleeting but impressive forms communicated by the gestures of passion in real life, he will be apt to acquire a manner incurably frigid.

Of Mechanical Drawing, or Copying.

The student who wishes to study drawing thoroughly, must equally learn to copy prints, and drawings, and nature, by the eye, but many may be able to shade a drawing agreeably, before they have made this proficiency, or who have no disposition to make it, but only wish to conquer the difficulties of forming an outline, for a purpose of utility. For such persons, and for use in all cases, where the precise imitation of the copy is of more consequence than any other circumstance, various means have been contrived to facilitate copying. We shall mention the most useful.

Of enlarging and diminishing by squares.

Divide any drawing or print to be copied into small squares, by ruling it with equidistant lines at right angles to each other. Divide the paper on which the copy is to be made into the same number of squares, and number the squares, in both pieces alike, by figures along the bottom and on one side, in order that the corresponding squares may be the more easily referred to. Draw in each square of the surface intended for the copy, exactly the same portion of the design which the original contains in the corresponding squares, and the copy will be com

pleted. This contrivance affords the means of making very accurate copies; the greater the accuracy desired, the smaller must the squares be made.

If the copy is intended to be larger than the original, the squares must be made larger; if less than the original, the squares must be made less; and the procedure afterwards will be the same as before. In plate III, where the process is exemplified, fig. 3 or 4, may therefore be considered either as the original or the copy.

If fine lines be drawn across an original, with a soft pencil, they may be erased without injuring it; but as it may often be desirable to avoid making lines upon a valuable original, lines may be drawn with a diamond, or with lamp-black ground with gum water, upon a pane of glass of sufficient size. The glass may then be laid upon the original, and the lines will answer the same purpose as if they had been drawn upon it.

Another method to avoid marking the original, is; to have a frame with threads stretched over it in squares, which may be placed against the original, in the same manner as the glass just mentioned.

The Pentegraph.

The pentegraph is an instrument sold by the mathematical instrument-makers; it equally answers the purpose of enlarging, contracting, or drawing of the same size as an original, but it requires the original to be traced by a blunted point, which is not always an admissible practice. When this is no objection, it is very convenient for copying complex designs; where long, straight, or parallel lines occur, the tracing point may be guided by a ruler. The usual price of the instrument is two guineas and a half, made of brass, and graduated in such a manner, that the reduction or enlargement of the original, may, within certain limits, be made in any degree required. It should be used upon a smooth and level table, or a true design cannot be obtained.

Tracing against the Light.

This mode of copying is familiar to almost every school-boy. It consists in holding up the design intended to be copied to the light, as against a pane of glass in a window, and placing a piece of paper designed for the copy upon it, the lines which are seen through the paper are traced with a pencil. The vertical position of the glass being irksome, this mode of copying may be better executed by, having a pane of glass put into a separate frame, then placing it in an inclined position, like a desk, with a candle at a suitable distance underneath it, to afford the light for tracing.

Tracing upon transparent Paper.

If thin paper be rendered transparent by means of oil, every line of any design upon which it is laid, may be distinctly seen through it, and traced upon it with the nicest accuracy. Transparent paper is usually prepared, by brushing over thin wove writing paper with a mixture of equal parts of spirits of turpentine and drying linseed oil. The coating is very thin, but it communicates to the paper, with a high degree of transparency, a pliability which enables it to bear creasing without injury. Cathery communicated to the Society for the Encouragement of Arts, &c. the following recipe, as an improvement in the mode of preparing transparent paper. Take one quart of the best rectified spirits of turpentine, and put to it a quarter of an ounce of sugar of lead finely powdered; shake it up, and let it stand a day and a night; then pour it off, and add to it one pound of the best Canada balsam, set it in a gentle sand heat, and keep stirring it till it is quite mixed, when it will be fit for brushing over the paper, which in about four days will be fit for use. Paper thus prepared takes the marks of the pencil better than the common kind, but it is more apt to turn yellow; and the coating forms a brittle varnish, which leaves an indelible mark if the paper be creased, or if a fine point be used upon it; hence it is not on the whole preferable. The paper rendered transparent, is generally that which the stationers call bank post; but where great nicety is required, tissue paper, which is still thinner, will be proper. Before it is brushed over with the mixture, after having been made slightly damp by laying it on another damp sheet of strong paper, it should be pasted by the edges upon a frame, and suffered to dry. When prepared and dry, it may be ruled or written on with a pen, if the ink be mixed with a little ox-gall.

Tracing with coloured Paper.

Take some hard soap and lamp-black, and mix them with water to the consistence of a jelly. Brush over one side of any thin smooth kind of paper with this composition, and let it dry. Place the coloured side of this paper upon a clean sheet, on a smooth table; over both these lay any design to be copied, and trace its outlines with a metallic or ivory point just sufficiently blunted to prevent its cutting the paper. The coloured paper, wherever it is pressed upon by the point, will make a mark on the white sheet it covers; and the lowermost sheet will by this means receive the whole design.

Instead of lamp-black, black-lead, vermillion, or any other colouring matter, may be employed.

In every kind of tracing, the different papers which are employed upon each other, should be fastened together by

wafers, or by doubling the edges of one paper over the other, and pasting strips to unite these edges at the back; otherwise they will be apt to get disarranged, and a loss of time will be suffered in recovering their position.

Stencilling.

Prick the outlines of the design to be copied with small pinholes, very near to each other. Place the design thus prepared upon a clean sheet of paper, and dust it over with powdered charcoal from a muslin bag. The charcoal will penetrate through the pin-holes, and upon lifting up the pricked paper, the design will be found upon the sheet beneath it The pricked paper will serve many times.

This mode of obtaining copies of designs is useful for ladies who work flowers upon muslin. The design which is pricked, may, it is obvious, either be an original, if it be thought proper to sacrifice that, or a copy made with tracing paper.

OF PAINTING IN OIL.

Having treated of the general principles of drawing, we come now to treat of the various styles and materials employed to produce the full effect of light and shade. This part of the subject includes Painting in Oil, Painting in Water-colours, Painting in Crayons, Painting on Glass, and several other varieties of painting not in general use. We shall treat in succession of the branches of art we have mentioned.

OF THE COLOURS EMPLOYED IN OIL PAINTING.

The colours employed in this, as in every other branch of painting, where the effect is to be the best that can be attained, must be pounded and levigated to an impalpable powder. The finest particles of mineral colours are generally separated by washing; which is performed by putting the colour into a vessel containing water, through which it is diffused by stirring; and when the whole has stood a sufficient time for the coarse particles to subside, the water with the remaining part suspended in it, is poured into another vessel, and left till it falls to the bottom. The product of this first washing, if not sufficiently fine, is washed once or twice more. When freed from the water by drying, the colours are ground up with oil, and preserved in bladders for use. The grinding slab and muller should be made of the hardest stone that can be obtained.

Linseed oil is used for common purposes; but the darkness of its hue renders it injurious to light colours; nut-oil is more

transparent, works more smoothly, and therefore is much to be preferred; it also resists more effectually any injury from exposure to the air; but poppy-oil is in all respects, except in price, preferable to any other kind;* it should always be used for fine work.

Sometimes the oils with which colours are mixed, are rendered drying, by boiling them upon the oxide of lead. This is done for work which is to be hastily finished, and is only fit for productions designed to answer a temporary purpose, as their beauty is apt to decay in a short time, by the scum which they inevitably acquire.

In all cases, the artist should use his colours in the simplest state possible. Simple colours are brighter and more durable than compounded colours; and of compounded colours, those are best which contain the fewest ingredients to produce the desired effect. Crystallized colours should be deprived of as much of their water of crystallization as their nature admits, before they are mixed with oil: this is done by exposing them in the state of fine powder, to the heat of a stove, or that of the sun.

Colours are generally purchased for painting ready prepared, put up in bladders; and it is of great consequence to obtain those prepared by persons who are not only honest but skilful. Strachan's colours have been found to possess most desirable qualities; and his great experience and skill as a chemist, entitle him to confidence.

Reds.

Vermilion is a bright scarlet; it is a chemical compound of mercury and sulphur, see page 372, of this volume. The finer it is washed, and the more complete its levigation, the paler and more beautiful it becomes. Stands tolerably well if perfectly pure.

Red lead, or minium, a red of an orange tinge. Very liable to turn black.

Indian red, an ochre brought from the East Indies. Its shade inclines to purple. Works freely, and stands well.

Colcothar, the red oxide of iron, obtained by the distillation or calcination of sulphate of iron. It is often called common Indian red, but inclines to scarlet instead of purple. Stands.

Venetian red, a coarse ochre, chiefly used in house-painting to imitate mahogany.

Spanish brown, a native ochre, still coarser than the above.

Burnt terra di Sienna, is raw Sienna, calcined till it becomes red. It has an orange shade, is not very bright, but is valued for its semi-transparency, smoothness, and durability.

Red ochre, is yellow ochre, calcined till it becomes red. It is not very bright, but, like all the ochres, it is durable.

Red chalk, is mostly used as a crayon, but stands well in oil.

Lakes are usually prepared from cochineal, precipitated by a solution of tin: or from the scarlet rags dyed with cochineal, and boiled in a lixivium of potash deposited upon cuttle-fish bone: or from the extract of Brazil-wood deposited upon chalk, which forms the common lake called rose-pink. Durable and beautiful lakes are now prepared from madder, by Sir H. Englefield's process. Lakes are transparent in oil; and as carmine does not work freely with this vehicle, they are the only substitutes for it.

Yellows.

King's yellow is a chemical combination of sulphur and arsenic, and a strong poison. It has a deep rich colour, but is not durable, nor very often used; and, like all arsenical compositions, the use of it may not only endanger the health of the artist, but will injure other colours.

Naples yellow is prepared from lead and antimony. It is much used, and stands tolerably well: but no iron must touch it, as the contact of that metal will change it to black.

Yellow ochre is a native earth. Some specimens are very bright, and all are durable. When finely levigated and washed, it is therefore much used, as it works very freely.

Masticot, or yellow oxide of lead, a dull colour, but stands well.

Unburnt terra di Sienna is a brighter and deeper yellow than most of the other ochres.

Turbith mineral is brighter and cooler than any other yellow, except king's yellow. It works like vermilion, which it resembles in its strength of colour.

Blues.

Ultramarine is the richest and brightest of all blues, perfectly durable, and in oil transparent. It is prepared from *lapis lazuli*, and is sold at the high price of ten guineas per ounce. If fine, it will bear exposure to a red heat without changing its colour.

Prussian blue. Its quality is finer in proportion as it is bright, deep, and cool. The sooner it is used after grinding, the more freely it works, and the better it appears. Stands.

Blue verditer, is obtained by adding quicklime to a solution of copper in nitric acid, and mixing up the precipitate with a small portion of quick-lime. It is a full blue, moderately bright, but devoid of transparency, and liable to turn greenish or black; this tendency is sometimes checked, by using it with white.

Smalt is a powdered glass obtained from cobalt. It is strewed upon any ground colour before it is dry, and forms a shining surface of a purplish colour, sometimes used as a ground for signs and large sundials.

Bice consists of smalt finely levigated. It is rather lighter, but its texture prevents its being in request, although durable.

Indigo is the deepest of all blues, and very durable. The darker and brighter it is, the better its quality. Guatimala indigo is the most esteemed.

Greens.

Verdigris is an oxide of copper, prepared by means of a vegetable acid. The best has a full blue green colour, and somewhat of a crystalline texture. It is changed to a grass green by the addition of a yellow colour.

Brunswick green, commonly called mineral green, is copper dissolved in a solution of muriate of ammonia.

Terra verte is a native blue green ochre. It is semi-transparent, durable, but not very bright. Its texture is coarse, and therefore it requires, like all the other ochres, careful washing and levigation. A very bright kind of this earth is found in Hungary.

Whites.

Flake white is an oxide of lead by a vegetable acid. The best comes from Italy, where the acid of grapes is employed to prepare it. It is very pure white at first, but changes in time almost to black.

White-lead, or *ceruse*, is the white oxide of lead prepared in this country with vinegar. Its colour is inferior to the above, and it fades sooner.

Zinc white, the white oxide of zinc by the sulphuric acid, precipitated by super-tartrate of potass. Stands well, and works freely.

Whites should be mixed with the clearest oil, and as they sink into the ground, a white ground is particularly proper for them.

Blacks.

Lamp-black is of a brownish hue, but mixes well with oil. Its quality is determined by its lightness and fulness of colour. It dries slowly, but may be improved in this respect by calcination in a closed crucible.

Ivory black is prepared by the calcination of ivory and bones in close vessels. It is a valuable colour, when pure, and properly levigated. That from ivory is the best; the other being reddish. It is often adulterated with charcoal, which gives it a blue cast. It is used for shading blues, and with white lead for a pearl gray.

Blue-black is made by the calcination of vine-stalks or tendrils in close vessels. Peach-stones and cherry-stones, burnt in the same way, also afford blue-black, which, with white, produces a silver white not otherwise obtainable.

Browns

Brown pink is the colouring matter of fustic or French berries, tinged by the addition of pearl-ashes, and precipitated upon chalk or cuttle-fish bone. It is transparent, but not durable.

Umber is a light brown ochre; by a slight calcination its colour is darkened; if inclosed in an iron box, when heated, the colour becomes more mellow. Stands well in both states.

Asphaltum is a brittle, bituminous substance, of a deep rich brown colour. It is dissolved in spirits of turpentine, and is semi-transparent; it is therefore used for glazing, and instead of brown pink.

Prussiate of copper, a very fine brown, see page 383 of this volume.

Compounded Colours.

Ash colour.—A mixture of black and white.

Bay colour.—A bright red, with a little brown or black.

Carnation colour.—Lake and white.

Crimson.—Lake, with a greater proportion of white than the last.

Flame colour.—A bright red and full yellow.

Flesh colour.—Red, yellow and white, according to the shade required.

Hair colour.—A light and dark yellow, with brown, black, and white.

Lead colour.—A deep blue and white.

Lion-tawney.—Deep red and yellow, united with brown.

Orange.—Bright red and yellow.

Pink.—A light red, with a little white and yellow.

Purple.—Blue and bright red.

Russet.—Black and white.

Scarlet.—A bright and dark red, as vermilion and lake.

Sea-green.—Yellow and light blue.

Sky-colour.—For the lowest part of a serene sky, light yellow and white; for the next portion, light blue and white; and the blue alone for the highest portion: all the colours to be imperceptibly blended into each other.

Water-colour.—Blue and white, heightened with white and shaded with blue.

Implements used in Oil-painting.

Pallets are thin pieces of hard wood, ivory, or any other light material, upon which are disposed a small supply of each of the colours for immediate use. They are usually of a shape nearly oval, and on one side contain a hole for the thumb to pass through in holding them.

The *pallet-knife* is mostly a thin well-tempered blade of steel, for mixing up the colours upon the pallet. An ivory one should be at hand for Naples yellow and other delicate colours, which steel might injure.

Pencils are either camel-hair pencils, or those called fitches. The former have been noticed before; the latter are also in general made of camel's hair, but are much larger, and put into tin tubes.

Tools are made of fine bristles, bound round a stick. They are of various sizes, and have a greater degree of stiffness than camel's-hair pencils or fitches.

The *easel* is a frame for supporting the picture. It is varied according to the fancy of the artist; but in general it has three straight legs, which open out and stand triangularly, and the painting is supported on the upper part of two of the legs, by pins which are moveable, and can be supported at equal and convenient heights in these legs. For small paintings, a piece of board is easily laid across the easel.

A *mall-stick* is a slender rod of wood, with a ball of cotton or some other soft substance at the end of it. It is intended to support the right hand, by resting the ball of cotton upon the piece, which, from its softness, it will not injure. The best artists generally decline the use of it, as it hinders the perfect freedom and command of pencil; but for coarse work it is useful.

Progress of a Picture.

Oil-paintings are generally executed on canvass, which should be strong, but not very coarse, and rather close in its texture. A kind of ticking has lately been much used, and linen is very suitable for small pieces. The first operation is to prime the cloth, which consists in covering it with a smooth coat of any colour. The particular tint of the priming is of little consequence, provided it is not dark, and is composed of a colour not likely to injure those laid upon it by a chemical

action. Ochres make the safest priming, and for ordinary work their cheapness is a recommendation.

In the subsequent management of the picture different artists follow different methods; but it will give a general view of the subject to observe, that the outlines of the figure may be faintly sketched with white chalk, and afterwards more correctly gone over with lake, or some other thin transparent colour. In the next step, the larger parts are laid in with their proper colours, lights, and shades. Some judgment may now be formed of the piece as a whole, and great care should be taken that every part be accurately expressed. Some of the colours, it will probably be perceived, must be kept down, others heightened, and some of the tints changed. In the next or finishing process, force and relief must be particularly studied. Freshness of tint must be given to the carnations, or flesh-colour; where much pains has been taken, a few smart touches may conceal the appearance of it; all the large shadows should be thin of colour, but nearly of the same tone, according to their situations; the lights should be distinct, bold, spirited, and will be more durable, if loaded with colour.

The picture should be frequently viewed at the distance for which it is intended, and its full effect ought to be observable at that distance: when the light in which it is to be placed can be ascertained, it should be adapted to it.

In painting landscapes, it is usual to begin about the centre of the piece; working upon the sky first, and advancing from the distance to the fore-ground. Whatever forms the background to an object, should be treated before the object itself, to spare the trouble which would be occasioned by painting round the object.

To complete a well-coloured picture, it should be *warm* and *mellow*: by the first term is meant, a certain moderated resemblance to the effect of sun-light, which being always yellowish, and more or less glowing, indicates that choice of colours, as allied to warmth: if we consider yellow as warm, green is not so warm, because it approaches to blue, which is the coldest of all colours, and is by this property rendered the most difficult to introduce and manage: although it may not be omitted, as it is a source of variety and opposition. Mellowness must regulate warmth; not permitting a positive yellow, which would be raw and offensive, yet inserting yellowish:—not a staring red; but reddish.

One coat of colour should be dry before another is laid on. To know when any coat is dry, breathe firmly on it; if it takes the breath, it is safe. Although any colour may be retouched,

after it is dry, and even changed to its opposite, yet the practice of reversing or materially varying colours, is not very prudent, as an under colour will impair the tone of a superior one, which is of a very different nature.

Water-colours are made paler by mixing with them a larger quantity of water; but oil-colours admit not of a corresponding practice; an extraordinary quantity of oil would in general render the colours more apt to fade, and impoverish them; they must therefore be heightened by the use of other colours of a lighter tone, as light red upon dark red. Some colours may, however, be mixed thinly with oil, and are laid over colours of a similar class, which require to be lowered. Thus, to give richness to crimson, it is often coated with lake. This practice is called *glazing*.

If a tint, different to any on the pallet, is required, while at work on a picture, it is better to mingle the colours which compose it on the pallet with the knife, than with a pencil; because the portion taken up by the pencil, will be apt to want uniformity of colour.

Every colour should have its own pencil, to preserve as much as possible the freshness of the colour. When the pencils and pallet are done with, they should be cleansed with spirits of turpentine, and afterwards with soap, if intended to be laid by for some time.

As colours have a more brilliant appearance when wet with oil, than when they are dry, the artist must carefully study the art of making the requisite allowances for this circumstance

PAINTING IN WATER COLOURS.

This pleasing and useful branch of painting is practised by a greater number of persons than any other. It has several important advantages peculiar to itself. It requires but few materials, and the most important of them are cheap; a picture may be left in any stage of its progress, almost at a moment's notice; the whole operation is cleanly; the colours are rich and delicate; it admits of a degree of distinctness and precision admirably adapting it to mathematical and architectural designs; and to the delicate productions of the vegetable kingdom.

Of the Colours used in Painting in Water-colours

Reds.—Vermilion, red lead, carmine, burnt ochre, lake, rose pink, common Indian red, Venetian red, Spanish brown.

Yellows.—Gamboge, masticot, Naples yellow, Dutch pink, English pink, gall-stone, English ochre, Roman ochre, French berry wash, turmeric wash, zedoary wash, and tincture of saffron.

Blues.—Ultramarine, Prussian blue, verditer, indigo, smalt, bice, and litmus.

Greens.—Sap-green, verdigris, distilled verdigris, and terra-verte.

Whites.—Flake-white, white-lead, troy-white, zinc-white, egg-shell white.

Black.—Indian ink, lamp-black, ivory black, blue-black, burnt cherry-stones.

Browns.—Umbre, Spanish liquorice, bistre, Cologne earth.

Of the colours produced by mixture, the following will answer most purposes.

Ash-colour.—White and lamp-black, indigo and black, cherry-stone black and white. The shades to be done with ivory-black.

Bay-colour.—Vermilion, with a little Spanish brown and black.

Bright red.—Indian lake and vermilion.

Carnation.—Lake and white, shaded with lake.

Cloud-colour.—Lake and light masticot; lake and white, shaded with blue verditer.

Crimson.—Lake and white, shaded with lake.

Flame-colour.—Vermilion and orpiment, red lead and masticot, heightened with white.

Flesh-colour.—White, with a little lake and red-lead; and yellow ochre for a swarthy complexion.

French green.—Light pink and Dutch bice, shaded with green pink.

Glass gray.—Ceruse, with a little blue.

Hair-colour.—Masticot, umbre, yellow ochre, ceruse, and cherry-stone black.

Lead-colour.—Indigo and white.

Light blue.—Bice, heightened with ceruse.

Lion tawney.—Red-lead and masticot, shaded with umbre.

Murrey.—Lake and flake-white.

Orange.—Red-lead and a little fine masticot, shaded with gall-stone and lake.

Orange tawney.—Cinnabar, light pink, and a little masticot shaded with gall-stone and lake.

Purple.—Indigo, Spanish brown and white; blue bice with red-lead and flake-white; or blue bice and lake.

Russet.—Cherry-stone black with white.

Scarlet.—Red-lead and lake, with or without vermilion; carmine and Indian lake; native cinnabar and red-lead shaded with Indian lake.

Sea-green.—Bice, pink and white, shaded with green pink

Sky-colour.—Light masticot and white, for the lowest parts; blue bice and white for the middle; blue bice alone for the highest part. These different shades are to be softened into each other at the edges.

Sky-colour for drapery.—Blue bice and Venice ceruse; or ultramarine and white, shaded with indigo.

Straw-colour.—Yellow masticot, and a very little cinnabar shaded with dark pink.

Violet-colour.—Indigo, white and cinnabar lake; or fine Dutch bice and lake, shaded with indigo; or litmus, smalt, and blue bice, the latter most predominant.

Water.—Blue and white, shaded with blue, and heightened with white.

Preparation of Water-colours.

When water-colours are prepared for use, they are mixed up with a solution of some slightly glutinous substance, such as gum, isinglass, or size; but whatever be the glutinous substance employed, its solution in water must not be so strong as to prevent the colours mixed with it from rubbing down freely with water afterwards. Gum arabic is the substance mostly employed, though the use of it is in one or two

respects exceptionable; for even when the purest and whitest pieces are selected, it will, in common with all other gums, in some degree darken, and rather injure the tone of bright colours, and it dries so hard, and shrinks so much, as sometimes to crack the colour. To prevent the latter defect, a little sugar-candy may be added to the gum, and the colours will then also work more freely.

A quarter of an ounce of gum-arabic put into a tea-cupful of hot water, will form a solution of a moderate strength, and proper for most purposes.

When isinglass is employed, half an ounce of it may be boiled in two pints of water, till it is dissolved, when the solution may be strained, and it is then fit for use.

Size is, however, upon the whole, preferable to any other glutinous substance, and it may be prepared by boiling clean shreds of parchment or white leather in water, till, when cold, it has the consistence of a jelly.

A little coloquintida may be added to the gum-water or size, to prevent flies from injuring the work in which it is used.

Distilled water should be employed for the solution of gum, for size, and in all the other operations connected with the preparation of colours, where it can be conveniently obtained. Where it cannot be obtained, the purest rain-water should be preferred: spring-water is the most improper, and often contains ingredients which will materially injure flake-white and some other bright colours.

To obtain water-colours in their best state, the method of preparing them must be varied according to their nature: Vermilion, red-lead, scarlet ochre, common Indian red, true Indian red, Venetian red, yellow ochre, masticot, ultramarine, bice, indigo, verditer, Cologn earth, umbre, terra-verte, brown ochre, white lead, calcined hartshorn, ivory black and blue black, should be ground extremely well with water only, and then washed over; they must then be mixed up with strong gum-water or size, by means of the pallet-knife, until they have the consistence of a paste, in which state they may be put into small muscle or other shells, or made into cakes by means of wooden moulds.

Prussian blue lake, and Naples yellow, should be reduced to an impalpable powder by levigating them on the stone with spirit of wine: then they, as also carmine, bistre, Dutch pink, and English pink, should be mixed with weak gum-water, by means of a small muller or pallet-knife, and put into their proper shells.

Indian ink, gamboge, sap-green, and gall-stone, require no

gum-water or size, but are merely rubbed down with fair water into a shell or on a piece of marble.

Verdigris is prepared by dissolving it in vinegar; when the vinegar is saturated, the clear part of the solution is poured off, and kept in bottles for use. Verdigris may be also prepared by dissolving it in the juice of rue, instead of vinegar; its solution in this menstruum is preferable for miniature painting, and in all cases where the solution has to come in contact with other colours, especially vegetable colours, to which vinegar would be injurious.

Litmus blue is prepared by boiling litmus in small-beer wort, till about one-fourth of the fluid is evaporated; it is then strained, and put into bottles for use, after being reduced to a proper state for working by the addition of water. The decoction or tinctures of yellow berries, zedoary root, Brazil-wood, log-wood, and saffron, are made with water, and preserved in the same manner. Turmeric wash is obtained by the infusion of turmeric root in proof spirit.

When tinctures are found upon trial to be too light, they may be deepened by slowly evaporating a part of the fluid; when too deep, it is only necessary to add water to them.

All the colours which will take a solid form are generally made up into the form of cakes, and when they are used, they are rubbed out with water upon a Dutch tile, or into small hollows made in a piece of marble, or upon a small ivory pallet held in the hand. When a pallet-knife is employed, it should be made of ivory, as iron or steel would injure several colours.

A fitch is employed to free the colours from dust, previous to their being rubbed out.

Directions for Painting in Water-colours.

Having provided the colours and materials which will be required for any piece, brush the colours, particularly those in shells, with a fitch kept for the purpose. Keep a sheet of waste paper under the hand, to prevent the piece from being soiled, and to try the colours upon. Lay the colours but thinly on at first, deepening and mellowing them by degrees. In general, the quicker the colours are laid on, the evener and cleaner the drawing will appear, and therefore it is necessary to work with a full pencil. When the work is done, wash the pencils in clean, warm water.

The flesh-colour employed should always be lighter than

the complexion to be imitated; as it may easily be lowered by working on it. For the cheeks and lips, use a mixture of lake and red-lead, or carmine, as occasion requires; and for blue tints, as under the eyes and in the veins, use indigo, or ultramarine and white.

In colouring landscapes, after the outline has been perfectly finished, lay dead colours all over the piece. This ought to be done with care, yet with a degree of freedom, which, though it may give an appearnce of roughness, is still pleasing. Afterwards sweeten the tints with a small pencil, to remove any harshness of the edges, and to make the shadows glide into one another. The dead colouring or aërial tint, is intended to imitate that haziness which the atmosphere always imparts to objects, according to the distance at which they are situated. It may be composed of Indian ink, indigo, and lake; the blue must be the prevailing colour for the most distant parts; towards the fore-ground, the Indian ink must be more and more prevalent, and near the ground-line may be used alone.

Having laid on the dead-colouring, begin first with the distances and lightest parts of the sky, where the yellowish beams of the sun are to be done with masticot and white, for the brightness of mid-day; but with burnt terra di Sienna for the mellow tints of evening: then proceed to the blueness of the sky, and deepen the colouring gradually, in ascending from the horizon, except in tempestuous clouds. To make the colour of the sky spread more evenly, it is a frequent practice to sponge the paper with clean water, and to begin to lay on the colours as soon as the water has entirely disappeared from the surface. The indistinctness of all objects must be increased as they recede from the eye, and distant mountains must be touched so faintly as nearly to blend with the aërial tint.

In colouring foliage, boughs, and branches, the dark parts must be put in first, with sap-green and indigo; for the light parts use sap-green alone, and it should pass over the limits of the gray tints.

Where it may be necessary to preserve perfectly the whiteness of the paper for the lights of stained drawings, Alston recommends the use of a raw yolk of an egg, as preferable to any other substance. The yolk must be mixed with water till thin enough to spread easily: a camel-hair pencil must be then dipped into it, and the lights to be preserved must be covered with it: after the dead-colouring is laid on, and the paper is dry, the yolk may be removed by crumb of bread, and the paper will be left pure.

OF PAINTING IN MINIATURE.

Miniatures are painted with extreme precision and brilliancy, to bear the closest inspection. They may be executed either with oil or water-colours; and according to the vehicle employed for the colours, the painting of them may be deemed a branch of painting in oil or water-colours. It is most usually practised as the latter, and such we shall consider it in the present essay.

The colours employed for this style of painting are the same as those used in the ordinary practice of painting in water-colours; but they are selected with scrupulous attention to the excellence of their quality, and they are used rather thinner. A little ox-gall is generally mixed with green, yellow, black, and brown colours, in order to make them spread freely by removing their disposition to greasiness. The rest of the materials, as well as the colours, are also the same as in water-colours, except that the surface drawn upon is generally either vellum or ivory.

The hair-pencils which are employed should be of the most perfect form, according to the directions given at page 701, but it will by no means be necessary to use the smallest which are made. Sable pencils are much used, as, for making fine lines and dotted work, no other kind answer equally well. When the pencil is too full of colour, it is usual to bring it to a fine point, by putting it between the lips, and touching it with the tongue; but this practice must be avoided in the use of orpiment, red-lead, and other poisonous mineral colours. The pencil may be drawn to a point upon the waste paper usually kept under the hand while painting. The pallet employed is generally not broader than the hand.

The ivory used in this kind of painting is in the state of thin leaves, such as are sometimes employed for memorandum books, instead of asses' skin: to prepare the surface, it is scraped with a knife, and washed over with the juice of garlic, to remove any greasiness which might prevent the colours from adhering.

The outline of the miniature is traced upon the ivory with a silver point, fixed in a case, and pointed like a pencil. The touch of this instrument should be extremely light and delicate. It is afterwards gone over with thin carmine, and made as correct as possible; if any erroneous lines appear, they are taken out with finely pounded pumice-stone rubbed on with a paper or leather stump. When the outlines are completed, the piece is dead-coloured, and in this part of the process, the

shadows are left very tender, and the lights strong, as the full effect is afterwards produced by dotting. In a portrait, begin the shades with vermilion and carmine, giving the strongest touches at the corners of the eyes, next the nose, under the nose, the ears, and under the chin, the fingers, and in every part where separations are to be marked out in shades that are obscure. Lay in the bluish shades with indigo, on such parts as recede from the light, as the temples, under and in the corners of the eyes, on both sides of the mouth, a little on the middle of the forehead, between the nose and eyes, on the side of the cheeks, the neck, &c. Yellow tints are composed of ochre and vermilion, and are given on the sides of the nose towards the bottom, under the eyebrows, a little underneath the cheeks, and on other parts which rise and come forward to the light. It is these tints which principally show the complexion.

The next object of attention is the back-ground, in the colouring of which there is a considerable diversity of practice: dark back-grounds may be composed of bistre, umbre, or Cologn earth, with black and white; others have a yellow cast, principally by the use of ochre. Black, white, and a little indigo, form gray back-grounds: Dutch pink, white, and black, make a greenish, or olive ground, which has a rich appearance. Back-grounds should be formed at twice, first laying on a very light thin tint, and afterwards a darker of the same colour, perfectly even and smooth.

The dotting by which the picture is finished, is sometimes effected by distinct separate dots, but this process is very slow, and is apt to have a harsh effect; it is a much better practice, therefore, to use little strokes which cross each other every way, till the work has the appearance of being dotted. It is called dotting, though it has a much softer effect than dots can be made to exhibit. The colours must glide into one another by insensible gradations. The shadows may be dotted with greenish tints, and where they are strong may be finished with bistre and vermilion, or terra di Sienna. The colour of the ivory may be preserved for a middle tint. Dot the clear and bright parts with carmine and a little vermilion, using a minute portion of ochre to lose and blend them in the shadowy parts; and care must be taken to give the strokes the different turns of the flesh, to produce a plumpness of the figure.

The lips are dead-coloured with vermilion and white, and shaded with carmine or lake. The dark touches, or markings, will require bistre.

The whites of the eyes are shaded with blue; the corners

next the nose with vermilion and carmine; the balls of the eyes are done with indigo and white, adding bistre if they are brown or black; if gray, the pupils are done with pure lamp-black. Shade the balls with indigo, bistre, or black, according to their colours; shadow the marking of the eyelids with carmine and bistre, which must be softened with the other tints. Give the little speck of light reflected from the pupil of the eye, with pure white. It must be on the side next the light. A narrow circle of pure vermilion, round the pupil of the eye, gives it great vivacity, and has an excellent effect.

The hands are coloured like the face, observing that the joints and ends of the fingers are a little redder than the rest. For the markings, use carmine and bistre.

Hair is dead-coloured with bistre, ochre and white, or black, according to its colour, and finished with pure bistre, mixed with ochre or black, the lights with ochre. The roots of the hair next the face must be softened into the blue tints. Great care should be taken to give the hair a soft appearance, and to intermingle the strokes which represent the curls in a natural manner.

Draperies are to be done with broad strokes of the pencil, like back-grounds.

The colouring of landscapes in miniature is similar to that in the ordinary use of water-colours, excepting a more general use of the finest colours, and the dotting, by which all the colours are mellowed, and the clouds rounded in appearance, in consequence of the softening of their edges.

Of the Colours adapted to particular Objects.

For *Black drapery.*—Lamp-black and white, shaded with pure lamp-black: to give the lustre of velvets, &c. use indigo in the dark shades.

Blue drapery.—Prussian blue, or ultramarine and white, shaded with indigo. Verditer shaded with indigo.

Green drapery.—Prussian blue or verditer, and Dutch pink, shaded with sap-green. Different greens may be formed by using more or less blue or yellow.

Purple drapery.—Lake, blue and white, finished with lake and indigo. Vary by adding more blue or lake.

Red drapery.—Red-lead or vermilion, shaded with carmine or lake.—*Carmine drapery:* form the shades with vermilion, and finish with carmine; the dark touches with bistre

White woollen drapery.—White, with a little ochre or gamboge. Shade with bistre.

Yellow drapery.—Yellow ochre, Dutch pink, gamboge, or Naples yellow, shaded with terra di Sienna and bistre.

Lace.—Dead-colour with blue, black, and white; finish with pure white; when it lies transparent over draperies or carnations, finish the under parts first, then paint the lace over it with pure white, and shade with the first colour.

Gold lace.—Dead-colour with ochre, and finish with Dutch pink and red-lead.

Silver lace.—Blue, black, and white, finished with pure white

Pearls.—White and a little blue for the dead-colour; shade with light blue; the speck of light in the middle with pure white, and a little yellow transparent tint on the shadow side to round them.

Diamonds.—Lamp-black, the lights touch with pure white. All other jewels are painted in the same manner, only changing the dead-colour

Water.—Indigo and white, shaded with indigo, or a dark mixture of indigo and white. Pure white for the bright parts and foam. Water must never be dotted; when smooth, it is shaded with horizontal strokes; when ruffled, the strokes follow the figure of the waves.

Trees.—Ochre for the dead-colour of the trunks, with white and some green for the light parts. For foliage, use verditer and sea-green, shaded and finished with the same, mixed with more or less of a lily green, according to the distance. The yellow tints of autumn must be given by ochre and white, finished with gall-stone.

Sky.—For a pure mid-day sky, ultramarine and white for the upper part; vermilion and white as the sky approaches the horizon, gall-stone and white for the lowest and pale part. For a dark sky, use indigo, black, and white, for the ground, with ochre or brown: obscure red for the clouds, and masticot for their lights.

As the ivory used for painting in miniature, is, from its thinness, semi-transparent, it is usual to cover the back of it with white paper; this heightens the tone of the colours; but silver leaf, applied in the same way, has a much more brilliant effect.

OF PAINTING TRANSPARENCIES.

Transparencies are pictures intended to be viewed at night by lights placed behind them. They exhibit, with peculiar force and beauty, all scenes requiring intense lights and shades, such as moonlight scenes, fires during the night, and similar objects, in connection with antique towers, woods, and desert places, inside views of cathedrals, and other scenes which dispose the mind to sentiments of awe.

The paper designed for a transparency must be fixed on a straining frame, such as that of a drawing board without its pannel, so that it can be held up between the eye and the light in the course of the work. The drawing, after having been executed in the usual manner of water-colour painting, must be held up to the light, and the effect desired being attended to, the shadows must be strengthened by additional coats of Indian ink; and to produce the requisite effect, some of them must be laid on both sides of the paper. For the strongest shadows of all, ivory black or lamp-black must be mixed with gum-water, which will produce a shade perfectly impervious to light.

When the picture is brought to its proper tone of colour, finished and dry, all the parts where the highest degree of transparency is required must be touched on both sides with a pencil containing spirits of turpentine, and those parts which require a less degree of transparency only on one side. Immediately afterwards must be applied in the same manner to the same places as the turpentine, a varnish composed of one ounce of Canada balsam, dissolved in an equal quantity of spirits of turpentine. This varnish renders the transparency permanent, for that produced by the essential oil alone would soon disappear. When the varnish is dry, the flame, if any occur in the scene, must be tinged with red-lead and gamboge. The moon must remain the colour of the paper.

Paintings of this description might be rendered subservient to a useful purpose for which they have not been adopted. If the diagrams illustrating philosophical lectures were executed in this manner, they would possess a degree of force and perspicuity well calculated to render them distinct to a large audience; and if optical diagrams were transparencies, the lecturer would not have occasion to say that black lines represented rays of light.

OF PAINTING IN CRAYONS.

Crayons, or pastils, are coloured substances which naturally possess, or are reduced by art, to the texture of chalk; they are used for sketching and painting, in their dry state, in the form and manner of a black-lead pencil.

Crayon painting is usually executed on strong blue paper, the thicker it is the better, provided it be free from lumps, and not very rough in the grain. The knots may, however, be levelled with a penknife, and the grain may be made smoother with a piece of pumice-stone. The sketch having been made upon the paper, and dead-coloured, the back of the paper is pasted and fixed on a smooth linen cloth, previously strained upon a frame. A sheet of clean paper is then laid on the face of the drawing, and is pressed with the hand, until it adheres to the cloth in every part. The crayons will now adhere better to the paper than before.

As colours in crayons cannot be compounded at the moment of using, with the facility of colours in oil or water, in a complete set of them every distinct shade will require a separate crayon. The only mixture they admit, is of a limited nature; sometimes little separate heaps, scraped from different crayons, are formed upon white paper, and small rolls of paper, or clean glove-leather, a little pointed, are used to take up the colours as wanted, and rub them in, and the finishing is given with crayons.

Painting in crayons allows considerable scope for the genius of the artist, and may serve to teach him a masterly freedom of touch, which he may transfer to other kinds of painting with great advantage. The whole effect is produced by strokes and dots, which must be varied in their direction according to the texture and figure of the object to be represented.

The tempering of crayons is found to be an operation of considerable nicety, to avoid their being so hard as to impart an insufficient supply of colour, or on the contrary so soft as to crumble away, and to be little better than a powder upon the paper. A variety of slightly glutinous fluids have been proposed, to give them the due degree of coherence, but the strength and the kind of fluid used requires to be varied, according to the nature of the colour employed, as the following view of the subject will evince. Crayons are always pointed by drawing the knife from the extremity, and not over it, as in pointing a pencil.

Of the Colours and Preparation of Crayons

Reds.

Vermilion, alone, and with different proportions of chalk, finely ground, and mixed with ale-wort, rendered slightly glutinous by boiling, and to which gum tragacanth has been added in the proportion of about a scruple to a pint of the wort. The vermilion, as in all other cases of preparing crayons, is mixed with the fluid, till it becomes a smooth paste, when it is formed into slips or pencil shapes, and dried by a gentle heat. The less the proportion of chalk, the stronger should be the wort.

Red-lead alone, and with chalk, prepared in the same manner

Red chalk requires no preparation but that of cutting it into slips with a saw.

Scarlet ochre and common Indian red, may be treated like vermilion.

Lake, alone, and with different proportions of pearl white, must be used for crimson crayons. It should be mixed up with skimmed milk or common gin.

Pure carmine is generally rubbed in by means of a roll of leather, or paper, on account of the expense of forming entire crayons of it; but when mixed up with a considerable proportion of white, this objection to its being made into crayons is removed. Gin or milk should be employed, as these fluids are less injurious to bright colours than wort.

Yellow Crayons.

Turpith mineral, with pale ale-wort, in the same manner as vermilion, and mixed with different proportions of chalk.

Dutch and English pink make crayons of an agreeable shade, but the colour is not durable. They are sometimes so compact as to require no preparation but that of cutting into slips; other specimens require preparing with skimmed milk.

Yellow ochre, in its natural state, or purified by grinding and washing over, and mixed up with skimmed milk.

Orpiment forms a valuable crayon in point of colour, but its disagreeable smell, and poisonous nature, render it objectionable.

Green Crayons.

Crystals of verdigris, ground to an impalpable powder in spirit of wine, and formed into a paste like vermilion, but dried without heat, form a bright green.

Verdigris treated in the same manner, forms a blue green crayon.

Prussian blue and turpith mineral, or Prussian blue and Dutch pink, in various proportions; also turpith mineral, with verditer or blue bice. All these mixtures require strong ale-wort.

Indigo with Dutch or English pink, prepared in the same manner as the above.

By the addition of different proportions of chalk, different shades of all the above greens will of course be procured.

Blue Crayons.

For deep blue, Prussian blue with skimmed milk, or ale-wort, or indigo prepared in the same manner.

Verditer and bice, with strong ale-wort containing gum tragacanth.

Ultramarine is used in the same manner as carmine.

White Crayons.

White chalk, in its natural state, is superior to any artificial composition. It should be selected of the most coherent texture, and only requires to be cut with a saw, in square slips of a convenient size, for example, about three inches long, and a quarter of an inch in diameter. These slips are rounded by taking off the corners with a knife.

For a brilliant white, flake-white is made into a crayon with milk, but as it is apt to change, it is not to be recommended.

Black and Gray Crayons.

The charcoal prepared from the willow, makes good black crayons; but the black chalks, mentioned at page 702, are the sorts most commonly used.

Ivory black is prepared with strong ale-wort, containing a little glover's size; and a small proportion of deep Prussian blue or indigo is sometimes added to the composition.

Gray crayons are formed of ivory or lamp-black, with different proportions of chalk.

On white paper, a soft black-lead pencil forms an excellent gray crayon.

Orange Crayons.

Turpith mineral, with red-lead or vermilion, forms a bright orange. It may be mixed with milk strengthend by gum tragacanth.

Dutch or English pink, with vermilion or red-lead, may be prepared with milk alone

Purple Crayons.

Deep Prussian blue and carmine, mixed with milk, form a very bright purple.

Deep Prussian blue and lake, prepared in the same manner, form a purple of the next degree of excellence.

Indigo and lake form a purple of inferior brightness, and not so deep: vermilion and indigo is paler still; it is prepared with ale-wort, containing a little gum tragacanth.

As all purples are composed of red and blue, it is obvious that their shades may be varied, by varying the proportions of their component parts.

Brown Crayons.

Brown ochre and bistre form a very full brown; they may be mixed up with ale-wort, moderately strong.

Spanish brown and umber, either alone, or mixed in different proportions with each other, or with true Indian red, with a small addition of ivory black in some cases, will form a great variety of useful shades of brown.

Fuller's earth, mixed with rather strong ale-wort, forms a good light brown, the shade of which may be darkened by a little Spanish brown.

Chalk is employed to lessen the intensity of all browns.

Methods of fixing Paintings in Crayons

It is obvious that the marks made with chalk and all other crayons can be but very slightly attached to the paper, and that they are extremely liable to be injured and defaced. Various means have therefore been resorted to for fixing them, in such a manner that, without having their tints injured, they may be enabled to bear rubbing.

One of the simplest means for this purpose, consists in drawing the crayon-painting through skimmed milk. This answers well for pictures of a small size, as the milk effectually prevents black-lead pencil or crayon strokes from being affected by Indian rubber; it is also more easily practised by most persons than another mode, which consists in passing the drawing once through a rolling-press with a damp paper upon it. A weak solution of gum-arabic or isinglass size, answers the same purpose as milk. When the picture is made on unsized paper, Cathery recommends the back to be brushed over with

a size made of half an ounce of isinglass, and two drachms of powdered alum, boiled for a quarter of an hour in a quart of water, and strained. This size, used milk-warm, penetrates the paper, and effectually fixes the picture. He also recommends another way, which is applicable to large drawings, done on sized paper; it consists in sponging with the glutinous fluid, a piece of unsized or blotting paper, of the same size as the picture. This wetted paper being laid flat upon a table, the face of the picture is pressed upon it in every part. The chalk thus becoming wet with size, adheres to the original surface, and by taking care wholly to avoid the smallest sidewise motion, whilst the two surfaces are in contact, the colours are not in the least daubed; nor is the minute quantity of colour transferred to the blotting paper any injury to the piece.

OF COLOURING PRINTS AND MAPS.

T... paper of the print or map intended to be coloured, must first be examined, whether it is sized or unsized. Unsized paper is generally used for taking off copper-plates, because it receives a better impression than the other; and such paper it will be necessary to prepare for the reception of colours, by steeping it in a strong solution of alum; even if it have been weakly sized, it will be advisable to brush it over with a solution of the same kind. Paper which bears ink well, may be considered as sufficiently hard for colours.

The colours required must be those employed in water-colours. They must be varied in kind according to the object in view; where a slight degree of colouring or rather staining of the print is proposed, thin colours will answer the end, and the shades of the engraving will be fully preserved. Where a richer and warmer effect than this will produce is required, strong body colours must be employed, and the original shades, though they must be attended to and govern those which are laid on, will be almost entirely concealed. Sometimes transparent colours are laid over the print, and afterwards the effect is heightened by body colours; this combination of the two modes of colouring prints has a good effect.

In performances of this nature, the use both of black and white colours should be studiously avoided, as they have a

cold unpleasant effect. Generally the thinness of the colouring will render white unnecessary, and for the broad lights, the mingling of colours nearly similar in tone, is preferable to the introduction of white. The same artifice will often supersede perfect blackness; but where black cannot be dispensed with, it must be used sparingly and with address, to prevent its impairing the mellowness of effect which should always be aimed at.

The colouring of a print, it must be obvious, is governed by the same principles as painting; great care must therefore be taken to soften the outlines of all objects, and to suffer an indistinctness to prevail proportionate to their distances; and the colours and mode of treating particular objects, will be similar to the directions before given on the subject of painting.

The colouring of maps is in fact only a species of staining; all the colours employed must be of the transparent or wash kind, and even such an approach to opacity as might obscure the original delineations, by too great a depth of colour, must be carefully avoided. The red usually employed is a decoction of Brazil-wood, or that prepared by boiling scarlet rags with the addition of pearl-ashes. The yellow is gamboge, or the extract of French berries, of fustic, of turmeric, or of saffron. For blue, a very weak solution of sulphate of indigo. For green, sap-green, and the solution of verdigris in vinegar, or of crystals of verdigris in water. For brown, Spanish liquorice and the decoction of tobacco. A great variety of colours would be improper for this purpose, as it is contrast that is chiefly wanted; black and white are never required.

In laying on the colours, the size of the camel's hair pencil should be proportioned to the surface to be gone over. Each colour should be laid on rapidly, in order that no part may be dry before the whole space is covered, otherwise it will scarcely be possible to attain that evenness of tint which is indispensable to a good effect. At the same time care must be taken to keep each colour within its proper limits. A sufficient contrast in the colours lying next each other, must always be observed, and the work must be finished by marking the boundaries of each district or province, according to the nature of the map, with a narrow line of a much deeper hue than the rest.

OF PAINTING ON GLASS

The several modes which have been adopted to paint on glass may be reduced to three:—1. The colouring matter of a print may be transferred to one side of the glass, and coloured: this is often called back-painting; and the pictures executed in this manner are put into frames, and viewed in the same manner as glazed prints:—2. Transparent oil-colours are employed, which merely lie on the surface, and suit such subjects, as the pictures of a magic lantern:—3. The colours are vitrified, and become a part of the glass itself. The first and third modes of painting on glass are those which claim notice in this place.

Of Painting on Glass, or Back-painting.

This mode of painting is executed with great facility; there are no outlines to draw, no shadows to insert, and it produces a soft and pleasing effect. In the first place, select a good mezzotinto print, cut off the whole of the marginal or white paper, and put it flat in water to steep, where it must remain till thoroughly wetted and softened. In the mean time provide an even pane of the best crown glass, free from knots and scratches, and lay on one side of it, with a painter's brush, a thin smooth coat of turpentine, thinned by the addition of a little spirit of turpentine. If the print has been taken off on unsized paper, it will be sufficiently wet in a couple of hours; if on sized paper, which is very uncommon for the purpose, it will be proper to let it remain in the water for four and twenty hours. When it is taken out of the water, press it slightly between blotting paper, to take off the superfluous moisture, and then lay it flat upon a table with its face uppermost. Take now a pane of glass, and place it upon the print in such a manner, that the surface covered with the turpentine shall touch every part of the print as nearly as possible at the same instant. Turn up the print, which is now attached to the glass, and place it between some sheets of paper under a moderate weight, for an hour or two, or press it with the hand till no blisters are observable. When this is done, wet the back of the print with a sponge, and rub the paper with the fingers, which will bring it off in small rolls, till at length nothing but the ink which formed the impression will remain. When this is dry, brush it over with a pencil dipped in spirits of turpentine, and it will become perfectly transparent, and fit

for painting. In painting it, the lights and shades must be preserved as in the original; and all the light colours must be laid on first. The colours to be used, are those employed in oil-painting.

Of Painting on Glass with vitrifiable Colours.

All the colours employed for this kind of painting, must be susceptible of vitrification, or they cannot combine with the glass, and become transparent. They are composed of metallic oxides, as no other bodies possess the requisite properties; and to facilitate their vitrification, they are generally combined with a flux, or soft kind of glass, which melts at a heat much inferior to that required for melting the ground or glass painted upon. The glass employed as the ground, is generally the best and clearest of that kind called crown glass, which is hard, and not easily melted. Such pieces should be selected as are free from specks or waves. The first step is to make a complete coloured drawing in water-colours, the design to be painted on glass. The glass is then laid over this drawing, and the outlines, as they appear through it, are drawn upon it with a pencil containing the colour for black, mixed with gum-water.

When a great number of separate pieces of glass are to be combined to form one picture, the joining should be made to fall as much as possible on such parts of the design, as may be least injurious to the general effect, as in the contours of the figure, and folds of the draperies; and when the situation of the different pieces has been fixed, by placing them upon the drawing, and tracing as for a single piece, the corresponding parts of the glass and drawing are marked, with letters or numbers, in order that they may be readily distinguished.

The colours are prepared by grinding them to an impalpable powder, or if this is difficult to effect by grinding, they are washed over. They are then mixed with oil of spike, and applied to the glass with camel-hair pencils. The oil of spike is used merely as a convenient vehicle for reducing the colour to a state in which it may be used like ordinary paint. It totally evaporates, long before the colour vitrifies. Spirit of turpentine would answer the same purpose, but it has not the advantage of the same unctuosity. A weak solution of gum arabic may also be used instead of it; but this vehicle leaves in the burning a residuum of carbon, which injures light colours.

Different shades of the same colour are produced by the greater or less diluted state in which they are applied to the glass, and nothing but experience can effectually teach the

exact procedure requisite. The thinness of the coat applied will not always be sufficient, and therefore a dilution with a greater or less quantity of colourless flux must be resorted to.

Most colours sink only a very little way into the glass; but the yellows, when the glass is only thin, will pass entirely through, and are besides apt to spread beyond the limits within which they were applied by the pencil; they are therefore to be used with considerable caution.

Whiteness is produced in this kind of painting by leaving the glass entirely unstained, as the unmodified light passing through the pure glass, is the nearest approach to whiteness of which the art admits, consistently with transparency.

As soon as convenient after a sufficient number of pieces have been painted, they should be taken to the furnace, as the drying of the oil of spike would leave the colours in a state susceptible of being easily disturbed.

The furnace is made of brick from twenty to thirty inches square. An aperture is made six inches from the bottom to receive the fuel; some bars are placed across the furnace, like a flooring, above which is another aperture to receive essay or trial pieces of glass. Upon the bars or flooring is placed an earthen pan, at the bottom of which are placed two or three layers of pulverized quicklime, with pieces of broken glass between them. The use of the lime is to give a more regular heat to the painted glass, the first stratum of which is laid upon the uppermost layer of lime, and all the pieces to be burned at once, are in like manner disposed horizontally with a layer of the powdered quicklime between them, and the top or last stratum of glass is overspread with the same powder. The furnace is then covered with tiles, and luted close, with the exception of four or five small apertures, to serve as chimneys.

The heat of the fire should be inconsiderable for the first two hours, but afterwards should be raised gradually to the heat required for the fusion of the colours. This point must be ascertained by occasionally examining the trial pieces, put in at the small aperture above the flooring; but when the point at which the colours fuse has been known by previous trials, the use of a pyrometer would be preferable.

As soon as the colours are fused, the intensity of the fire should be abated, and suffered gradually to cool. The process generally requires about twelve hours, and a kind of fuel should be used, which will fill the whole interior of the furnace with flame.

For staining glass upon a small scale, a chemical muffle may be employed; and as the nearness of the pieces of glass is of

no consequence, if they be only prevented from touching, several pieces may be put into the muffle, by using, to separate them, plates of iron with a small ledge on each side, to prevent the under side of the plates from touching the upper surface of the glass beneath them.

Of the Colours used in staining Glass.

Red.—Take of the flux, No. 1, (the composition of which is mentioned below,) six parts; of gold precipitated by tin (see page 367 of this vol.) one part. When these ingredients are thoroughly mixed, they are ready for use. The colour thus prepared produces a fine crimson, inclining to purple; its strength may be increased by adding more of the oxide of gold.

Yellow.—Take of either of the fluxes six parts, of calcined silver two parts, and of antimony half a part. Vitrify them, and then levigate them for use. The colour is a deep bright yellow proper for shades; where great transparency is wanted, the antimony may be omitted.

The silver is prepared by covering thin plates of silver with sulphur, and exposing them to a red heat.

If sulphate of iron be dissolved in water, and precipitated by pearl-ashes, this precipitate, used instead of antimony, will produce a very cool and true yellow, proper for forming greens with blue.

Blue.—To the flux No. 2, add a sixth or an eighth part of ultramarine, and keep it in fusion till the ultramarine vitrifies. To darken the colour without increasing the quantity of ultramarine, zaffer fluxed with borax may be employed.

A deep and very good blue may be prepared with zaffer, one part of which may be mixed with four parts of either of the fluxes, with a little borax. Vitrify the mixture in a strong fire, and prepare it for use by levigation. A strong body of this colour will give the effect of blackness. For a weaker blue, the quantity of zaffer must be diminished.

Green.—Take of either of the fluxes, six parts, and of precipitated copper one part. Vitrify and afterwards levigate the mixture in the usual manner. The colour will be a deep green inclining to blue, but this shade may be modified by the addition of more or less of the colour for yellow.

The copper is prepared by dissolving it in nitric acid, and precipitating it by pearl-ashes. The precipitate in this and other cases may be separated by the filter, as the alkaline salt is not injurious.

Black.—Take of the flux No. 1, six parts, of zaffer one part, of glass of antimony half a part, and of scarlet ochre

and magnesia, each a fourth part. By fusion this mixture becomes a deep black.

By using the flux No. 2, instead of No. 1, the black glass will be softer. By the mixture of more or less of this glass with the reds and yellows, a great variety of browns may be produced.

Purple.—Take of the red prepared as above directed, with blue prepared from zaffer.

Orange.—For a bright orange, take the red and the yellow without antimony.

For carnation or flesh-colour, add glass of antimony, and either of the fluxes, till the colour desired is obtained.

Composition of the Fluxes.

Flux No. 1.

Take of the glass of lead one pound, of pearl-ashes six ounces, of common salt two ounces.

The glass of lead being reduced to a fine powder, and intimately combined with the other ingredients, the whole must be put into a crucible capable of retaining vitrified bodies, and fused. The lower the heat by which the fusion can be accomplished, the better; the operation should not therefore be hurried.

When the mixture has become transparent and free from air-bubbles, it may be poured out upon a clean iron plate. If the composition, when cold, is observed to be very foul, it should be reduced to powder, and re-melted, but if only a few foul specks are observed, they may be picked out. The good part may then be reduced to powder, and kept for use. This flux is moderately soft, and has a slight tinge of yellow.

The glass of lead is prepared by fusing two parts of red-lead, with one part of flints calcined, and finely levigated, or instead of flints, the finest white siliceous sand.

Flux No. 2.

Take of the glass of lead one pound, of pearl-ashes six ounces, of borax four ounces, of arsenic one ounce. This mixture, treated like the above, produces a very soft flux, with a strongly vitrifying power. It is therefore proper for metallic oxides which are found to fuse with some difficulty, and also to mix, for a second burning, with compositions to which harder fluxes have been previously employed.

Vitrified borax may be used, where an extreme fusibility in any composition is required.

ENGRAVING.

The term *engraving*, when used without any other distinction, is employed, 1. to denote a plate of copper, upon which any regular design is produced by indented lines or strokes; 2. the impression which, by means of a rolling press, is taken from a plate of this kind; the strokes and dots of which have been previously filled with ink; 3. the act by which the design is made upon the copper. The context alone points out the particular meaning attached to the word.

It is in the third sense that we employ the term engraving as the head to this chapter.

The art of engraving for the rolling press, is confined nearly to five different modes, which artists distinguish from each other by separate names: the first kind is simply called Engraving, or Engraving with the tool; the second, Etching; the third, Engraving in Chalks; the fourth, Aquatinta; the fifth, Mezzotinto.

OF ENGRAVING WITH THE TOOL.

The art of engraving with the tool is the most ancient of all the modes of engraving; and though, principally from the slowness of its execution, it is now but partially used, it is capable of a degree of spirit, force, and precision, which renders it admirable for historical designs, and which no other branch of the art is equally capable of producing. The instruments required to execute it are few and simple; they consist principally of gravers, dry-points, scraper, burnisher, cushion, and oil-stone.

Gravers are small bars of steel, of a square or lozenge form, and with the short handle into which they are fitted, are about five inches long. One of the angles of the bar is always on the under side of the instrument, and the point is formed by bevelling the end from the uppermost angle. The square form is used for broad strokes, and the lozenge for fine ones. The upper end of the handle is a kind of knob, with the under side

of it cut off, in order that the instrument may be used with the steel nearly in a horizontal position. The goodness of the steel, as well as its temper, is of consequence; gravers are generally too hard when first bought; but they should not be softened too hastily, as, after a little grinding and whetting, they will be frequently found to answer perfectly, although in the first trial they were found too hard. For the method of tempering, when necessary, see vol. 1, page 5. We may, however, remark, that if a graver will not make a mark upon common window glass, it is too soft. Towards the extremity, the graver should bend upwards a little, in order that the point may be more readily prevented from digging into the copper. The bevelled part, and the two sides which form the edge, should be rubbed upon the oil-stone in such a manner as to be quite flat. To take off any bur which may be occasioned by the whetting, the point is usually struck into a piece of box, or any other close-grained wood; and its sharpness is tried upon the nail; if it will cut the nail without leaving any jagged edge, it is fit for use.

The dry-point or needle consists of steel wire, with a small cylindrical handle, or it may be of a sufficient length and thickness to be held without a handle. It should be tempered like a graver, and have a fine conical point; and should be entirely free from any angular edge, otherwise it cannot be drawn upon the copper in every direction, without sometimes producing a roughness which ought not to occur. The art of whetting it perfectly, though apparently a simple operation, is not acquired without considerable practice. The dry point, when the bur which it raises is scraped off, leaves a softer and more delicate stroke than can be effected by any other means.

The scraper and burnisher are frequently made in the same piece, one at each extremity of a piece of steel, which is about seven inches long. The scraper has nearly the form of a triangular pyramid with the point cut off. It is used to remove the bur occasioned by the dry-point, and on similar occasions; any of its edges are used in this way. The burnisher is a cone, except that it is a little convex on the side; it is used to rub out scratches which appear on the plate, and to lessen the force of a line which has been cut too deep. The scraper and burnisher are each about an inch or rather more in length, and the middle part of the steel, is the handle by which they are held.

The oil-stone should be a piece of the best Turkey hone used with olive oil.

The cushion is a bag of leather filled with sand. It should be about three inches thick, and always less than the plate to

be engraved. The plate is rested upon it, and may by means of it be more readily turned round, or in any direction, to produce the curves required.

Parallel rulers and compasses will be required as in drawing; the former should have a brass edge; and the latter should be entirely made of steel, with a spring instead of a joint at the head, and with a screw to regulate the opening of the limbs.

The surface of the copperplate designed to be engraved should be perfectly polished, very level, and free from every imperfection. The directions for polishing plates are given in vol. 1., but they are better and more cheaply prepared in London than elsewhere. When the plate is ready, the next point is to transfer to it an exact copy of the outlines of the design to be executed. For this purpose, heat the plate in an oven, or hold it over one or more candles, till it will melt white wax, a piece of which should then be rubbed over it, and allowed to spread till it forms a thin uniform coat over the whole surface; after which the plate may be left upon a table till it is cool. In the mean time, take a piece of transparent paper, the directions for preparing which are given at page 729, and fastening it upon the original design, in the usual manner for tracing, draw the whole of the outlines in the most accurate manner with a black-lead pencil. The outline thus sketched, may be turned down upon the white wax with which the plate is coated, and upon its being subjected to the action of a press, such as is used for packing, or kept between several thicknesses of paper, under a heavy weight, for an hour or two, on taking it out, the lines on the transparent paper will be nearly eradicated, but a lively copy of them will be found transferred to the white wax on the plate, in the reversed position which is necessary to make an impression of the finished plate resemble the original. The pencil marks on the wax being now traced with a fine steel point, so as just to touch the copper, the wax may be melted off, and a perfect outline of the design will be found on the plate. When any small subordinate part of a design is to be transferred to the plate, the process is the same, except that the transparent paper is merely held down on the plate, and rubbed on the back with the burnisher instead of pressing.

It is now necessary to use the graver, the knob of the handle of which should rest against the hollow of the hand, the fore-finger extended towards the point, the thumb on one side, and three fingers on the other, in such a manner that the graver may be applied flatly to the plate, pressed forward with greater or less force, or wholly stopped, as occasion requires, in any part of its progress. In forming straight lines, the

plate should lie steady upon the cushion; in forming curved lines, sometimes the plate only must be moved, while the graver is held steady; at other times both the graver and plate must be moved, according as the artist finds he can with most freedom produce the desired effect. The graver raises a slight bur on the sides of the strokes; these must be removed by the dexterous use of the scraper, which must be prevented from removing any part of the general surface of the copper. The real breadth and direction of the strokes may be seen by rubbing them with a roll of cloth containing oil, for the oil will sink into the strokes, and give them a blackish appearance. It should be remembered, however, that whatever diminishes the sharpness of the edges of the strokes, will diminish the sharpness of the impression they will yield, and therefore the oil-cloth should be gently used, and as seldom as convenient. When broad strokes are required, they should be made of several strokes very close together, and cut till they are a little below the general surface of the copper. By this means the bottom of the broad stroke will have a roughness which is necessary for it to retain the ink while cleaned by the printer but it is no hinderance to the ink being taken up by the paper. If the broad strokes were produced at once by the graver their depth would be such as to overload the paper with ink.

Scratches and very slight imperfections of the strokes, may be rubbed out with the burnisher; those which are rather deeper, will require the scraper, and afterwards the burnisher; but to take out the deepest strokes, the copper must be hammered up on the back, and when the defective part is so much raised, that the false strokes will disappear by reducing it to the general level, it must be rubbed as in polishing a plate at first, and finished with a piece of soft charcoal.

Engraving with the tool is principally employed for the finest historical pieces, and figures, where straight lines are inadmissable; and no instruction can be written which is comparable to what may be derived from studying the manner in which the most eminent artists, as Strange, Hall, Woollet, Bartalozzi, Heath, Sharp, and others, have expressed different subjects. Although strokes may be crossed in every direction, yet the crossing which produces the best effect, is that which leaves intervals of a medium figure between the square and the lozenge. Gently curved lines must always be employed for the exterior of the human figure, and where they are broken off, great care must be taken to prevent any appearance of hardness.

When sculpture is represented, as it is always supposed to

be white marble or stone, the engraving should be light and smooth, the eye should have no pupil, and a certain degree of stiffness or clotted appearance must be given to the hair. Linen should be represented by smaller and closer lines than other sorts of cloth, and by single strokes, except in some of the shades where it may occasionally be proper to have double strokes, to produce a good effect. Woollen cloth should have two strokes, and they ought to be fine or wide according to the supposed fineness or coarseness of its texture. In crossing the strokes, the second should be finer than the first.

Shining stuffs, such as silk or satin, require strokes which are harder and straighter than others; when their colours are bright, they are done with a single stroke; when dark, they require a double one; and the first strokes should be interlined by others which are finer. Shining metals, glass, and smooth water, require clean single strokes, interlined by finer, except at the place of strongest reflection, where the strokes should be single. For smooth water, the strokes must be horizontal; in ruffled water they must follow the course of the waves.

In representing mountains, the direction of the lines should be frequently interrupted, to shew the irregularities of the surface; but the greater the distance, the less of this should be perceived.

Dark clouds greatly exercise the skill of the engraver; and generally require two strokes. Sometimes one set of the strokes are curved, and the other straight; sometimes both are curved; but in all cases, the intervals are more lozenge than for other objects. A serene sky is represented by strokes parallel to the horizon, or by strokes following the same direction, but gently waved. According to the general rule for the sky, the strokes must be gradually stronger as they recede from the horizon.

In the lights of drapery, and other parts where a few fine strokes are required, they should be put in with the dry-point, as that will give them the utmost clearness and lustre of which the art admits.

The direct light of the sun falling upon copper, produces a glare which prevents the artist from properly seeing and executing his work. A screen is therefore employed, formed of tissue paper pasted upon a slight frame, which is placed in a sloping direction before the window at which the artist sits, and the light he receives passes through it.

Even of those engravings which are considered as wholly executed by the tool, the dark shadows, and such objects as trees, are usually done by etching, to which we now proceed.

OF ETCHING.

In this mode of engraving, the strokes and dots on the copperplate, instead of being cut with a tool, are corroded by an acid, by which means the effect of engraving is produced with great expedition. To perform it, the plate is covered with a thin coat of a resinous substance, upon which the acid employed has no action; the design, and all the lines it requires, are next traced with a steel point, so as just to cut through the resinous substance; an acid is then poured upon the plate, and allowed to remain on it, till it has corroded the metal to a sufficient depth in all the places where the tracing has been made.

The resinous composition which is laid upon the plate, is called the *ground;* and the instruments which are used to make the requisite lines upon it, are called *etching needles.* A dry-point may in fact be used as an etching needle, and *vice versa,* and the manner of whetting both is the same; but etching needles are required of several thicknesses. They generally consist of pieces of steel wire, about two inches in length, inserted into cylindrical handles of hard wood, about five inches long, and the third of an inch in diameter. The steel tapers gradually towards the point, except a small portion of the extremity, which is made conical. They are whetted in a small groove made at one end of the oil-stone.

Of Etching Grounds.

A great variety of compositions have been recommended for etching grounds, and almost every artist has some peculiarity in the mode of preparing the one he uses; but the general nature of the ingredients is in all the same. There are three kinds of grounds in use, the hard, the common, and the soft, and for each kind, the following recipes may be considered as of the best authority.

Soft Ground.

Take one ounce of white or bleached bees-wax, one ounce of asphaltum, half an ounce of common pitch, and half an ounce of Burgundy pitch. Melt the wax over a slow fire, in a pot of glazed earthenware; add to it the rest of the ingre-

dients by little and little, stirring the mixture all the time it is on the fire. The asphaltum should be pounded in a mortar before it is put in. Care must be taken to prevent its burning, by using a low heat. When the whole is thoroughly melted and incorporated, take it off the fire, throw the whole mass into a vessel of clean warm water, and knead it with the hands into balls about the size of walnuts, or a little larger.

In summer the ground should be made rather harder than in winter, by increasing the quantity of asphaltum, or continuing the boiling for some time after the incorporation of the ingredients.

Common Ground.

This composition is a medium between the hard and the soft ground, and is the most extensively used. Lowry, whose merit and success as an artist have never been excelled, is said to form it with three parts of asphaltum, two of Burgundy pitch, and one and a half of white wax. The asphaltum must be powdered and melted first, and the other ingredients being added as soon as it is in a state of fusion, are thoroughly mixed with it; the whole is then poured out into warm water, and kneaded into balls.

This is an excellent composition: it is adapted to temperate weather: in very cold weather, the proportion of pitch may be a little increased; for very hot weather, it may be hardened by boiling it rather longer than would otherwise be necessary. If in kneading the etching ground, any part of it should adhere to the hand, it may be entirely removed by a little fresh butter, having first rubbed off the principal part with a towel after warming the hands at the fire.

Hard Ground.

Take four ounces of fat oil, very clear, and made of good linseed oil, like that used by painters. Heat it in a clean earthen pipkin, add to it four ounces of powdered gum mastic, and stir the mixture briskly, till the whole be well combined. Then press the whole mass through a piece of fine linen, into water, and form it into balls like the grounds above described. This is the hard varnish used by Callot, and is called the Florence varnish. It answers perfectly well.

Preparation of the Copper for Etching.

The copperplate for etching is prepared in the same manner as for engraving with the tool, and it should be cleansed from greasiness by rubbing it with a clean cloth and Spanish white. To cover it with the ground it must be heated, as for example in a common kitchen oven, or by holding it over a chafing dish of burning charcoal. When it is hot enough, a ball of the ground to be used should be in readiness, tied up in a piece of tiffany, and should be dabbed all over the heated plate, till a sufficient quantity of it is melted, to form a thin coat. That there may be no bubbles, or want of continuity in the ground, which would be fatal to success in the subsequent operations, the ground should be dabbed and united with a ball of cloth, till it begins to stiffen; and the ground must never be heated so much as to smoke. The next operation is to blacken the varnish, which is done by holding the surface covered with it over the flame of one or more candles, according to the size of the plate, and moving it about till every part has been blackened by the smoke. The plate should never touch the snuff, and as soon as the blackening is complete, it must be left to cool in a place where it will not receive the least dust. The blackness of the ground renders every stroke made with the needle distinct, from the brightness of the copper which immediately appears.

To transfer the design to the ground, it must be traced upon transparent paper as for engraving with the tool, except that a pen and Indian ink should be employed instead of a pencil; this ink will easily mark the transparent paper, if mixed with a little ox-gall; another thin piece of paper must then be smeared with red chalk, which should be rubbed on till it covers the paper equally, and will not easily come off; the chalked side of this paper must be placed flat upon the ground on the plate, and the traced side of the transparent paper must be placed next to it, and both secured from moving by pieces of wax at the corners. In the distinctness of the design on the transparent paper, there will scarcely be any difference of the sides; and therefore all the lines may be gone over with a blunted steel or ivory point. On lifting up the papers, a distinct outline will be found upon the ground, in consequence of the red chalk adhering to it, wherever it received the pressure of the point. And as the back of the transparent paper has been traced upon, the design on the ground will be reversed, with respect to right and left, so that the impression

of the plate will resemble the original: but if the contrary be desired, it is only necessary to trace upon the right side of the transparent paper. The etching needle must now be used, and lines to form the outlines and shades must be traced with it, either by hand or with the assistance of compasses and parallel ruler, as the case requires; taking care to use different needles, according to the fineness or strength of the strokes required.

Oval-pointed needles are the most proper for strong strokes. The needle should be held as nearly upright as possible.

The varnish raised by the needle, to prevent its stopping up the lines in any part, should frequently be removed from the plate with a large camel's hair pencil. The whole design being completed, the plate is ready for biting.

Of Biting and Rebiting.

Previous to the use of the acid, the plate should be examined, and if any improper strokes have been made, or if the ground be any where broken up, a composition called the stopping mixture, must be immediately applied to it. This is formed of turpentine-varnish and lamp-black. It may be applied to the ground with a camel's hair pencil, and will, when dry, answer the same purpose as the original ground, either for tracing upon with the needle, or wholly to resist the acid: but when turpentine varnish is intended to be traced upon with the needle, it should only just be suffered to dry till it has lost its adhesiveness; as in the course of time it becomes brittle, and under the needle flies from the copper in flakes.

The design being complete, the plate is surrounded with a border or wall, about an inch high, composed of bees' wax, softened by the addition of one third of tallow. The common nitric acid of the chemists, diluted with something more than an equal quantity of water, is now poured upon the plate, to the depth of about half an inch. The acid will speedily begin to act upon the copper, where it has been laid bare by the strokes of the needle, and bubbles will immediately rise to the surface. These must be cleared away with a feather, as fast as they appear, and also such as are observed to adhere in the strokes.

When the faintest parts of the design are supposed to be sufficiently bitten, the nitric acid is poured off by a spout left for that purpose at one corner of the border, and only slightly stopped with a separate piece of wax. The plate is washed with water, and all the parts supposed to be sufficiently bitten,

are, when dry, covered with the stopping mixture already mentioned. The spout is now filled up, the acid poured on again, and the same operation repeated till all the shades are sufficiently bitten. The plate, after being washed, is then heated, and some olive oil being poured upon it, the ground is wholly removed with a linen rag, and the plate made clean with the oil-rubber. The dirt which remains in the lines may be washed out with spirits of turpentine.

No precise direction can be given for the length of time which the acid must remain upon the plate, and the real depth of the biting cannot be known, by examining a plate while the varnish is on it. From half an hour to an hour is the usual time for fine work, but for large designs of bold character, the trunks of trees, dark foregrounds, and other parts to be expressed with similar force, a day or even several days must be employed in successive operations of biting. The effect of the acid must be ascertained by scraping off a small part of the ground, to examine the plate; or by using a spare piece of plate, upon which a ground is laid, and lines drawn similar to those on the true plate, and trying what time the acid to be used requires for producing the effect desired. It is, however, to be observed, that the same acid will have different effects on the same copper, in seasons of different temperature, its its power being weakened by cold; and even so slight a circumstance as that of the sky becoming overcast and gloomy during the operation of biting, will retard the action of the acid.

When the ground is entirely cleared away, and any part is observed to be over-bitten, it may be corrected by rubbing it with the burnisher, if it be slight; but if the excess of biting be considerable, the copper must be rubbed down with charcoal.

When any part of the plate is materially too faint, it may be rebitten, but this is a very delicate and hazardous operation. A little of the etching ground being melted on a spare piece of copper, it may be taken up by the dabber, and dabbed upon the part to be rebitten in such a manner that it may not enter the former strokes, but merely adhere to the uncut part of the copper. The part is then surrounded with wax, and the acid used in the customary manner. The strokes to be rebitten, must, before the ground is again applied, be entirely cleansed from any foulness, by the use of spirits of turpentine, and afterwards rubbing the plate with the crumb of bread.

The art of etching in its infancy was considered as a spurious kind of engraving, and those who adopted it, from the facility

with which it was performed, were anxious to conceal their use of it, and to give their work as much as much as possible the appearance of having been executed with the graver. Hence they used the hard ground or varnish, as it produced the sharpest lines, and was best adapted to their purpose. But when the peculiar excellencies of the two arts were ascertained, etching was better appreciated; this concealment was nor longer necessary, and therefore the common ground, for general use, has entirely superseded the hard ground, because it admits of so much more freedom in the use of the needle.

Etching is peculiarly adapted to the expression of all objects which are termed picturesque, such as ancient buildings, cottages, rocks, uneven ground, trees, and verdure in general. This arises from the freedom with which the lines forming these objects may be drawn with the needle, which may be used in the same manner as a black-lead pencil, and also from a certain agreeable roughness left in the strokes when the acid is allowed to bite freely. But etching has also the apparently opposite property of being well adapted to smooth flat surfaces of every description. This arises from the uniform action of the acid in biting the strokes in every part alike; a property in which it can never be rivalled by the graver.

It has been mentioned, that plates professed to be done with the tool, are scarcely ever executed without some assistance from etching; it may be added, that the copperplates professed to be etched are scarcely ever committed to the press without some touches of the graver and dry point. The two arts mutually and essentially assist each other.

Here we must mention, as one of the most signal improvements which has been made in the art of etching, since its first discovery, the use of machinery to draw the lines upon the etching ground. All kinds of mathematical and mechanical designs consist almost entirely of straight lines and regular curves, the whole of which can be drawn by machinery, with a precision that the eye and hand can never equal. Lowry appears to have been the first who used machines in this way, and his performances are truly admirable. Machines for ruling equidistant lines, both straight and waved, are now commonly made in London; they consist of a straight bar of brass or steel, upon which slides a socket with a steady but easy motion. To the side of the socket is fitted a perpendicular tube, which receives a steel wire, or any other hard substance, called the pen. This pen has a point like an etching needle, and it is pressed down by the action of a spring. If then a copperplate, covered with the etching ground, be placed under the

ruler, which should be supported at each end, and raised about an inch above it, the point of the pen may be caused to reach it; and if the socket to which the pen is attached, be drawn along the bar, it will form a straight line upon the plate, more even, but in other respects the same as if that line had been drawn by hand with a ruler. Now if the plate or the ruler, after a line is drawn, be moved backwards or forwards, in a direction parallel to this first line, any number of lines may be drawn in the same manner, and a design consisting only of straight lines might be entirely completed. In the machines, therefore, a very exact screw, acting upon a box confined by a slide and connected with the bar, or the board upon which the plate rests, produces the requisite motion; and a contrivance or index is used to measure the exact portion of a turn required, before any stroke is drawn. Such is the principle of the machines most generally used; those for drawing curves, are adapted to the wants of particular engravers, and have hitherto been made under their own inspection. One remark, however, applies to them all; the point or pen employed, should not be made of steel, which, however well tempered, will require frequent wetting, and must therefore inevitably draw strokes deficient in perfect uniformity. The pen should have a diamond point, which, when once properly figured, remains constantly the same, and imparts an admirable degree of regularity and sweetness to the work: a diamond point has the further advantage, that the etching ground never adheres to it, as it does to steel.

As copper, though the most suitable of all the metals for engraving, wears very fast under the action of cleaning, which it requires for each impression taken from it, many attempts have been made to secure the durability of etchings by using glass instead of copper; for if glass be coated with wax, it may be etched by the same process as copper, using only fluoric acid instead of the nitric. The surface of glass would bear cleansing, without injury, incomparably longer than copper, if it could be made to sustain the pressure of the rolling press: this has been attempted, by bedding the plate of glass in plaster of Paris, but it is still so liable to sudden destruction as to prevent its being adopted.

OF ENGRAVING IN CHALK.

This mode of engraving is intended to imitate crayon drawings. It produces this effect by dots made near each other. It has of late years been much employed, and when carefully executed has a soft and pleasing effect.

The copperplate is prepared, and the ground laid upon it, in the same manner as for etching. In the tracing also of the design upon the ground, no difference occurs; but afterwards, in using the needle, no continued lines must be made either for the outlines or any other part, but dots only. The dots must be small in proportion as the work is intended to have a fine and smooth appearance; and their nearness to each other must be increased or diminished according to the depth or lightness of the shade required. Sometimes the dots are uniformly spread; in other examples they are disposed in lines, of two or three dots broad, with white spaces between, to imitate the separate strokes of a crayon. Both these styles may be introduced into the same piece, with the best effect. The dots frequently running into each other, is no disadvantage.

After the nitric acid has remained upon the plate a sufficient length of time for the lightest shades, it must be poured off, and those shades must be stopped with turpentine-varnish. The other shades are then stopped in succession, as in common etching; and if, after the ground has been removed, and an impression taken, any part is found to be too light, it may be rebitten, by a careful attention to the directions already given for that process.

After all the parts which require the least precision have been executed by etching, a considerable proportion of the labour of the best engravings in chalk still remains to be produced by the tool. To use the graver for making dots, it is the most convenient to reverse its situation in the handle, so that the angle which is undermost in the common mode of using it, will be uppermost, and it will then make the impression required upon the plate, while held in a much less inclined position than usual.

To diminish the labour of forming dots, small wheels with one or more rows of teeth in them, have been used; the effect produced by machines of this kind is deficient in precision and freedom, although they may be used in large works.

Engraving in chalk is well adapted to the human figure,

and also for flowers. It is a tedious operation, but requires labour rather than genius.

OF AQUATINTA.

An impression from an engraving in aquatinta resembles a drawing executed in Indian ink. Its appearance is soft and pleasing, and it is a style well adapted to ruins and picturesque scenery, where precision is not of much consequence. It is therefore greatly in vogue for landscapes; and it is recommended by the facility with which it may be executed.

The principle upon which aquatinta is performed may be thus explained: the copperplate, prepared in this customary manner, is sprinkled evenly with a resinous substance in powder; the plate being warmed, the resin adheres in a granulated form to the plate; the nitric acid is then poured on, and immediately attacks the copper, in all the innumerable interstices where it is left uncovered by the resin; and if an impression were taken of the plate, the effect would be like a wash of Indian ink. The different shades are produced by the longer or shorter time which the acid is allowed to act upon the plate.

In the ordinary aquatinta process, the plate is covered with a common etching ground, and the outlines of the design are etched in the usual manner. The ground being removed, the plate is slightly rubbed with the oil-rubber. It is then dusted with gum copal, reduced to a very fine powder, and sifted to make it even. The copal should be tied up in a muslin bag, and should be scattered by striking the hand which holds it against a ruler, or some other substance held in the other hand. By this means a very equal shower of dust may be obtained, which will adhere in some degree, on account of the oiliness of the plate; but any part which is loose, may be removed by striking the plate against a table. The plate may be then slightly warmed, till the gum changes colour, which will be an evidence that the adhesion of the gum to the plate is sufficient to resist the acid. If any part of the plate is to remain untinted, it must be covered with the turpentine-varnish used in etching; the plate is then surrounded with wax, and the nitric acid is poured on as in etching. As soon as the lightest shade is produced, the nitric acid is poured off, the plate washed, and every part sufficiently bitten is stopped with the

turpentine-varnish. The same operation is repeated for all the shadows, till, after three or four operations, the plate is finished.

In preparing the gum copal, it is, after being powdered, put through sieves which vary in fineness; the different parcels are kept in separate bags, and used in succession, beginning with the finest; for if the coarsest powder had not a fine ground to rest upon. it would produce a shade consisting of disagreeable daubs and clots. A great variety of resinous substances might be employed, but gum copal is the most suitable.

The time which the acid should remain on the plate, is best ascertained, as in common etching, by experiments on small pieces of spare plates.

The latest improvement which has been introduced into the art of aquatinta, has been made by J. Hassel, of London, who communicated his process to the Society for the Encouragement of Arts, &c. The following information on the subject is derived from his own account.

By this improvement, the artist can sketch his subject, with a black-lead pencil upon the copper, with as much facility as upon paper; and the art of engraving from this sketch is so simple and easy, that an artist can do it with five minutes' study. The trouble of tracing on oil-paper, and other retracing on the etching ground, is avoided, and the doubtful handling of an etching needle is done away, as the pencilling on the copper is visible in the smallest touch. It has also another perfection, that by using a broader instrument, it will represent black chalk.

This new plan is particularly pleasant for colouring up, to imitate the freedom of drawings, as the lines are soft, and blend in with the colour. It is a circumstance always objectionable in the common method of etching, that those so tinted can never be sufficiently drowned, nor destroyed, and always present a wiry hard effect. The plan is equally adapted to historical sketching, and might be the means of inducing many of our eminent painters to hand down to posterity their sketches, which at present they decline, from the irksomeness of retracing their performances, and the uncertainty of success with the etching needle.

The style in question differs essentially from what is termed *soft ground etching*: that process is always uncertain, cannot be repaired, and will only print about two hundred impressions; whereas, the specimens by the proposed plan will admit of being retouched if any part fail, and will print five hundred impressions with care.

Process of Drawing upon Copper, to imitate black-lead Pencil or Chalk.

A remarkably good polish must be put on the copper with an oil-rubber and crocus martis, (colcothar, or red oxide of iron,) well ground in oil, after which it must be cleaned off with whiting, and then rubbed with another clean rag. Then pour over the plate the solution to cause ground, which is made as follows:

No. 1.—Three ounces of Burgundy pitch,
One ounce of frankincense.

These are to be dissolved in a quart of the best rectified spirits of wine, of the strength to fire gun-powder when the spirits are lighted.

During the course of twenty-four hours, this composition must be repeatedly shook, until the whole appears dissolved; then filter it through blotting paper, and it will be fit to use.

In pouring on this ground, an inclination must be given to the plate, that the superfluous part of the composition may run off at the opposite side; then place a piece of blotting paper along this extremity, that it may suck up the ground that will drain from the plate, and in the course of a quarter of an hour the spirit will evaporate, and leave a perfect ground that will cover the surface of the copper, hard and dry enough to proceed with.

With an exceeding soft black-lead pencil, sketch your design upon this ground, and when finished take a pen and draw with the following composition, resembling ink: if a thin and delicate outline is desired, draw with a sharp-pointed pen; if the imitation of a chalk drawing is intended, a very soft and broad-nibbed pen will be necessary, or a small reed.

No. 2.—Composition, resembling Ink, to draw the Design on the Copper.

Take about one ounce of treacle or sugar-candy, add to this three burnt corks, reduced by the fire almost to an impalpable powder; then add a small quantity of lamp-black to colour it; to these put some weak gum-water, (made of gum-arabic,) and grind the whole together on a stone with a muller: keep reducing this ink with gum-water until it flows with ease from the pen or reed.

To make the ink discharge freely from the pen, it must be scraped rather thin towards the end of the nib, on the back part of the quill: and if the liquid is thick, reduce it with hot water.

Having made the drawing on the copper with this composition, dry it at the fire until it becomes hard; then varnish the plate all over with turpentine-varnish.

It will now be necessary to let the varnish, that is passed over the plate, dry, which will take three or four hours at least; but this will depend on the state of the weather; for if it should be intensely hot, it ought to be left all night to harden.

When the varnish is presumed to be sufficiently hard, you may rub off with spittle the touches made with the foregoing described ink, and use your finger to rub them up; should it not come off very freely, put your walling-wax round the margin of the plate, and then pour on the touches some warm water; but care must be taken it is not too hot.

The touches now being clean taken off, wash the plate well and clean from all impurities and sediment of the ink, with cold *soft* water; then dry the plate at a distance from the fire, or else in the sun, and when dry pour on nitric acid, which should, in cold weather, be prepared as follows:

To one pint of nitric acid, or strong aquafortis, add two parts, or twice its quantity, of soft water.

In hot weather, to one part of nitric acid, add three parts of water.

In every part of this process, avoid hard or pump water.

The last process of biting in with nitric acid, must be closely attended to, brushing off all the bubbles that arise from the action of the acid on the copper.

In summer time, it will take about twenty minutes to get a sufficient colour: in winter, perhaps half an hour or more. All this must depend on the state of the atmosphere and temperature of the room. If any parts require to be stopt out, use turpentine-varnish and lamp-black, and with a camel's hair brush pass over those parts you consider of sufficient depth: distances, and objects receding from the sight, of course ought not to be so deep as the fore-ground; accordingly you will obliterate them with the foregoing varnish, and then let it dry, after which the acid may be applied a second time, and repeat this just as often as you wish to procure different degrees of colour.

Every time the acid is taken off, the plate must be washed twice with soft water, and then set to dry as before.

To ascertain the depth of the work, rub a small part with a piece of rag dipped in turpentine, and then apply the finger, or a piece of rag rubbed on the oil-rubber, to the place so cleared, and it will give you some idea of the depth.

The walling wax is taken off by applying a piece of lighted paper to the back of the plate, all round the opposite parts of

the margin where the wax is placed; then let the plate cool, and the whole of the ground, &c. will easily come off by washing the plate with oil of turpentine, which must be used by passing a rag backwards and forwards, until the whole dissolves; it is then to be cleaned off by rags, and care must be taken that no part of the turpentine is left hanging about the plate.

If any part is not bitten strong enough, the same process is to be repeated.

The plate should only pass once through the press, in taking the impressions from it.

Directions respecting Grounds, Gum-water, &c.

No. 1.—The ground in hot weather must have an additional one-third of spirits of wine added to it for coarse grounds, to represent chalk; and one-half added to it for fine grounds, to represent blacklead pencil; and always to be kept in a cold place in summer, and a moderately warm situation in winter.

Gum-water must be made in the proportion of half an ounce of gum-arabic to a quarter of a pint of water.

Turpentine-varnish is composed of an ounce of black rosin to an eighth part of a pint of spirits of turpentine. If the weather is excessively warm, it ought to be made with a sixth part of a pint of spirits of turpentine.

Tracing-rag should be made of a piece of Irish linen, not too much worn, the surface of which is to be rubbed with another rag dipped in sweet oil, just sufficient to retain a small portion of vermillion or pounded red chalk. This must be placed with the coloured part towards the ground of the plate, and the drawing or tracing laid upon it, which must be traced very lightly with a blunt point or needle.

OF MEZZOTINTO SCRAPING.

Engravings in mezzotinto resemble Indian ink drawings; they differ from those in aquatinta, with respect to which the same observation is usually made; and yet mezzotintos and aquatintas differ from each other. The difference can scarcely be distinctly described, but on closely examining the shades of mezzotinto, they appear to be composed of lines or hatches crossing each other in all directions; while the shades of aquatinta, examined in the same way, have a granulated appearance. Mezzotinto has about the same degree of merit for portraits, that aquatinta has for landscapes.

The tools employed in this art are the grounding-tool, burnishers, and scrapers. The grounding-tool has the shape of a shoemaker's knife, with a fine crenelling edge. It is used to indent the plate with lines in every direction. The burnishers are like those used in etching, but are required of various sizes. The scrapers are formed of blades like a surgeon's lancet: they are also required of various sizes.

The copperplate designed for mezzotinto, is prepared in the same manner as for every other species of engraving. The first step of the process is to mark upon it the limits of the design, and within these limits the grounding tool is employed. It is pressed upon in an even, steady, and moderate manner, and with a rocking motion advanced over the plate, till the whole space within the limits is covered with lines. These lines are crossed by others at right angles. The two diagonal directions are then taken. The whole series of lines is then repeated several times, taking care not to enter the same lines twice; till at length, by the extreme closeness of the lines, the original surface of the copper is entirely destroyed, and if an impression were taken from the plate, it would present a uniform and completely black shade. This operation is called laying the mezzotinto ground.

To the ground thus formed, must now be transferred the outline of the design. The ground is blackened by the smoke of a taper, and the back of the design, or a copy of its outlines

on transparent paper, being rubbed with red chalk, is laid upon it, and the outlines traced with a blunted point. The red chalk on the back marks the plate wherever it receives the pressure of the point, and when the paper is removed, these outlines are rendered permanent by tracing them with a blunted dry-point upon the copper.

This progress having been made, it must be observed, that the original ground, without any alteration, serves for all the deep shades; but the lights, and light shades, are all produced by scraping or burnishing down this ground, either entirely or in part, the strongest lights being produced the first. The burnisher is chiefly used after the scraper, to clear the strong lights. As this process goes on, therefore, frequent proofs or impressions should be taken of the plate, to observe the effect; and if too much of the ground has in any case been removed, it must be again formed by a small grounding-tool.

OF ENGRAVING ON WOOD.

The wood most proper for engraving upon, is box-wood, which should be cut to the height of printing types, by slices from the trunk of the tree, cut at right angles to the pith. This is done in order that the engraving may be executed on the end of the wood, as the graver will not, in all directions, make a smooth stroke upon any other side of the wood, nor would the work be so durable, if the fibres did not stand perpendicularly, while the block would be more liable to warp.

The piece of wood being planed very smooth, the design is drawn upon it with a black-lead pencil; then every black line which the engraving is to exhibit, is to be left untouched, but all the intermediate spaces are to be cut out with the square or lozenge gravers, used to copper, or with tools of various sizes, with handles like gravers, and the same length, but shaped like chisels. In this process, it is obvious that manual dexterity is the main requisite.

In engraving upon copper, every part which is to be white must be left untouched, and the black lines must be indented: in engraving upon wood, every part which is to be white must be cut out, and the black lines must be left standing. This difference is demanded by the difference in the mode of printing.

Impressions of engravings upon wood, have not the precision and brightness of those from copper, neither do they bear close inspection so well, but they unite greater softness and force, when looked at from a little distance. Wood engraving has of all subjects succeeded the worst in depicting the human countenance; but to foliage, water, the trunks of trees, and old buildings, it is well adapted.

The principal advantages of an engraving upon wood, are, that it can be struck off at the same time as the letter-press of a book, and that at the lowest computation it will yield, without requiring repair, four times as many impressions as a copperplate. Hence it would appear that wood engraving is cheaper than that on copper; and this is really the case, when a moderate degree of excellence only is required. But let an engraving on copper, and the expense of the best mode of taking impressions from it, be set against an engraving on wood producing an equal effect, with the expense of the best impressions from it, and the copperplate will be found preferable: for the best mode of cutting in wood is very expensive, and the costliness of the best mode of printing engravings of this kind, overbalances the advantages derived from the greater number of impressions they will yield.

None but India paper will take very good impressions of wood-cuts, and paper of this description is not only scarce, but about five times the price of the best writing paper. Satin receives particularly fine impressions of engravings in this style; where there is much foliage, or water, the brightness of the lights admirably imitates the effect of sunshine.

It is a singular fact, that one process in the art of engraving upon wood, much practised by the early masters, is entierly lost. As those lines which are to appear white, in an impression taken from a wood block, must be indented or cut out with the graver, the crossing of lines, for shades, or for net-work, can very easily be effected, if those lines are to be white, and the ground black: but if the contrary be desired, viz. a white ground and black lines, reticulated work, which is technically called *cross-lining*, although very coarse, becomes to the wood-engravers of the present day, an undertaking of immense labour and difficulty. Yet the early artists produced black lines crossing each other, apparently with as much facility as shades con-

sisting of single lines, for some of them have introduced into a single piece, where they might have been spared, as much as would take a modern engraver years to accomplish. The circumstance of the large quantity of crossed shades which they produced, seems entirely to refute the supposition, that prodigious liberality of application, and not any peculiar secret, constituted their means; and conjecture has hitherto been exercised in vain to assign another explanation of their mode of working. The artist who shall revive or discover an easy mode of cross-lining, will contribute much to the improvement, and perhaps to the extended application of this useful but laborious art.

MISCELLANIES.

INKS.

Method of making Black Writing Ink.

In six quarts (beer measure) of water, boil four ounces of Campeachy logwood, chipped very thin across the grain. The boiling may be continued near an hour, adding from time to time, a little boiling water, to compensate the waste by evaporation. Strain the liquor while hot, suffer it to cool, and make up the quantity equal to five quarts by the further addition of cold water. To this cold decoction, put

1 lb avoirdupoise of blue galls, coarsely bruised, or
20 oz. of the best galls in sorts,
4 oz. of sulphate of iron calcined to whiteness,
half oz. of acetite of copper, previously mixed with
the decoction till it forms a smooth paste,
3 oz. of coarse brown sugar, and
6 oz. of gum Senegal or Arabic.

These several ingredients may be introduced one after the other, contrary to the advice of some, who recommend the gum &c. to be added when the ink is nearly made. The composition produces the ink usually called Japan Ink, from the high gloss which it exhibits when written with, and a small phial of which is sold for sixpence.

The above ink, though possessing the full proportion of every ingredient known to contribute to the perfection of ink, will not cost more, to those who prepare it for themselves, than the commonest ink which can be bought by retail. The recipe was given to the public by Desormeaux. It answers for copying letters by transferring from them an impression to a damp sheet of thin unsized paper, passing through a small rolling press.

When gum is very dear, or when no very extraordinary gloss is required, four ounces will be found sufficient, with one ounce and a half of sugar. The sugar is to impart a greater degree of fluidity, and consequently to make the ink flow more readily from the pen, than it otherwise would, when the quantity of gum proper to give a high gloss is used.

By using only twelve ounces of galls, to four ounces of sulphate of iron, uncalcined, (omitting the logwood, the acetite of copper, and the sugar,) and using only three ounces of gum, a good and cheap common ink will be obtained.

It appears of little consequence whether rain, river, or spring water is used; but it will always be safest to prefer one of the two former, where it can be obtained.

Lamp-black has been added to ink, to prevent its colour from being destroyed by the action of the oxymuriatic acid. It should be burnt in a closed crucible, to render it less oily. It causes the ink to write much less freely, although it may be useful for particular occasions.

Red Ink for Writing.

Boil over a slow fire four ounces of Brazil-wood in small raspings or chips, in a quart of water, till a third part of the water is evaporated. Add during the boiling two drams of alum in powder. When the ink is cold, strain it through fine flannel. Vinegar or stale urine is often used instead of water.

Blue Ink.

Take sulphate of indigo, which may be had of the dyers, and dilute it with water till it produces the colour desired. It is with this sulphate, very largely diluted, that the faint blue lines of ledgers and other account books are ruled. If the ink were used strong, it would be necessary to add chalk to it, to neutralize the acid.

Indelible Ink for marking Linen, &c

Dissolve in nitric acid any quantity of silver. This solution, if the silver has been alloyed with copper, will be of a sapphire blue.

In order to separate the copper from the silver, add to the solution twelve times its weight of distilled water, or, for want of it, rain-water, and suspend in it a thin plate of copper. In proportion as this plate dissolves, the silver will precipitate itself perfectly pure, in the form of a white powder. When no more of this powder will precipitate itself, the liquor should be decanted. The powder is then to be washed in a great quantity of water, until the water thrown upon it is no longer of a blue cast, but remains perfectly limpid. The powder thus obtained is silver in its purest state.

If this powder weighs one ounce, dissolve as much gum Senegal, and two drams of white glue (glue prepared from white leather or parchment will answer) in two ounces of distilled water. Mix this solution with three drams of lampblack well calcined in a close crucible.

To manufacture this mixture properly, it should be triturated in a glass mortar.

This operation being finished, the solution of silver, diluted in eight times its weight of distilled water, is poured upon the above mixture: the whole is then well stirred with a spatula, and the ink is made.

This ink is fixed upon the cloth by means of a mordant, which is thus prepared: Dissolve two ounces of white glue, and as much isinglass, in six ounces of alcohol, and as much distilled water. This solution will be made in two days. The *balneum mariæ* is made use of for the purpose; and care must be taken to stir the two kinds of glue from time to time.

After the whole is dissolved, it must be filtered through flannel, in order to keep back all its mucilaginous particles. The liquid thus filtered, is preserved for use in a bottle well corked.

The part of the linen intended to be marked, must be wetted with this mordant, which must be allowed to become perfectly dry on it. The part must then be rubbed smooth with an instrument called a polisher, which may be a piece of glass shaped like a pestle, or even the bottom edge of a common phial. The writing is then to be made with the ink, using a common hard-nibbed pen. Soap, or any other material used in washing, will take out the lamp-black, which is merely to give a stronger

colour to the fluid when it is written with; but it never has any effect upon the ink, or nitrate of silver, which itself forms a stronk black, after it has been a short time written with, and exposed to the light.

Sympathetic Inks.

Sympathetic, or secret inks, are those which are not perceived till the paper upon which they are used has undergone some preparation to render the characters visible. A great number of compositions of this kind are known.

If a weak tincture of galls be written with, the characters will be invisible till wetted with a weak solution of sulphate of iron: or *vice versa*, a weak solution of sulphate of iron will not appear till moistened with the solution of galls.

If a solution of alum be employed, the characters will be invisible till the paper is immersed in water, when they will be legible.

A solution of acetate of lead in water will not appear till moistened with a solution of sulphuret of potass, which renders it brown.

The marks of diluted sulphuric acid are not visible till the paper is heated, when they become black.

A weak solution of cobalt in nitro-muriatic acid will not appear when it is written with, but by warming the paper it assumes a lively green colour. This colour possesses the singular property of disappearing, or nearly so, when the paper becomes cold, but of becoming again distinctly visible when brought to the fire; and this effect will take place for an indefinite number of times. It has been sometimes used for drawings, which have all the appearance of representing barren and desolate scenes, but when they are brought to the fire, a lively and beautiful verdure charms the eye. It might therefore be used for fire-screens with a beautiful effect.

To make a blue sympathetic ink, dissolve cobalt in nitric acid, and precipitate it by potash: dissolve this precipitated oxide of cobalt in acetic acid, and add to the solution one-eighth of common salt. This ink appears and disappears under the same treatment as the last-mentioned.

As it is disagreeable to write with a colourless fluid, any of these inks may be mixed with cork, first burnt and finely powdered; when the writing is performed, the blackness may be removed by the use of Indian rubber, unless the paper has been scratched.

CEMENTS AND LUTES.

Cements for stopping the Fissures in Iron Vessels.

Take six parts of yellow potter's clay, one part of the filings of iron, and a quantity of linseed oil sufficient to form it into a paste of the consistence of putty. The paste should be beaten with a hammer to mix the ingredients. This composition is easily forced into the fissures of iron vessels, which when repaired with it, have been found to answer as well as if they had been renewed.—The clay should be freed from water, by drying it in the sun, or a slow oven.

Another cement to interpose between surfaces of iron, for example the flanches of the pipes and other parts of steam-engines, is made of two ounces of muriate of ammonia, one ounce of flowers of sulphur, and sixteen ounces of cast-iron filings or turnings. Mix them well in a mortar, and keep the powder dry. When the cement is wanted, take one part of this mixture, and twenty parts of clean iron filings or borings; grind them together in a mortar, mix them with water to a proper consistence, and apply them between the joints.

Blood Cement.

A cheap and strong cement may be formed by mixing bullock's blood with quick-lime. It soon hardens, and therefore should be used immediately after it is made. It is used by coppersmiths, to lay over the rivets and edges of the sheets of copper in large boilers, to prevent leakage, but may be used for a great variety of other purposes.

A cement having nearly the same properties as the above, is made by mixing drying linseed oil with quicklime.

Cements for Stone.

Plaster of Paris, used alone, is the cement which stone and marble masons place between the different pieces or joints of mantle-pieces, &c. but a better cement for jointing broken pieces of spars and stones, is formed by adding seven or eight parts of rosin to one of wax, and adding only a small quantity of plaster of Paris to strengthen it. The ingredients should be melted and thoroughly mixed together. In using this composition, the pieces of stone to be joined, should be made suf

ficiently warm to melt it, and should be pressed closely together, agreeably to the general rule, to leave as small a body of cement in the juncture as possible.

Gum mastic alone, used in the same manner as the last, namely, by heating the pieces till they melt it, forms a good cement, often used for agates and precious stones.

Linseed oil and chalk, form the putty so much used by glaziers. The cement is stronger when white lead is used with the oil instead of chalk; such a composition is frequently employed for the joints of stone-work.

A Solder or Cement which gives to broken Vessels of Glass or China their original strength.

The principle upon which this is accomplished, consists in using a composition which fuses into glass, at a much less heat than the pieces to be united.

Take two parts of white lead, one part of flint-glass, (of which table-glasses are made,) and one part of borax. Reduce these ingredients to a fine powder, and mix them well. This powder must be mixed with water, and laid upon the edges of the broken pieces, with a camel hair pencil. The parts are then to be joined properly together, and kept in that state, by means of wire. They are then placed in an oven, or in an iron pot over a charcoal fire gradually raised, till the composition melts into glass. The parts will be as firmly united as when new, and when struck, will ring or sound in the same manner.

The top of the pot, during the firing, should be closed with a tin-plate or iron cover, and the edges secured with clay; except a small hole through which the operator suspends a piece of wire, to which is attached a bit of china ware, with a little of the cement or flux upon it. By the examination of this piece of china, it is known when the operation of firing is finished.

Cements for China, Glass, &c. without heat.

Glass and china may be cemented by means of white paint, which is composed of linseed oil and white lead. This cement is merely a thin kind of putty. It holds with considerable firmness, and resists water; but is rather long in drying.

A strong cement, insoluble in water, may be made from cheese. The cheese should be that of skimmed milk, cut into slices, throwing away the rind, and boiled till it becomes a strong tenacious mass This water being washed off, it is

to be washed in cold water, and then kneaded in warm. This process is to be repeated several times. The glue is then to be put warm on a levigating stone, and kneaded with quick-lime. This cement may be used cold, but it is better to warm it; and it will join marble, stone, or earthenware, as well as china or glass, so that the joining will be very strong, and scarcely perceptible. When perfectly dry, it completely resists the effects of water, whether hot or cold.

Cement or Glue to resist Water.

A solution of shell-lac in alcohol, added to a solution of isinglass in proof spirit, forms a cement that resists water, and may be used as a glue. On cements of this nature, see page 121, vol. I.

Fire-proof and Water-proof Cement.

To half a pint of milk, put an equal quantity of vinegar, in order to curdle it; then separate the curd from the whey, and mix the whey with the whites of four or five eggs, beating the whole well together. When it is well mixed, add a little quicklime through a sieve, until it has acquired the consistence of a thick paste. With this cement, broken vessels and cracks of all kinds may be mended. It dries quickly, and resists the action of water, as well as of a considerable degree of heat.

Rice Glue.

This elegant cement is made by mixing rice flour intimately with cold water, and then gently boiling the mixture. It is beautifully white, and when dry is semi-transparent. Papers pasted together with this cement will sooner separate in their own substance than at the joining. It is in every respect preferable to flour-paste, for the purposes to which the latter is applied.

This compostion, reduced by the addition of water to the consistence of clay, may be employed for models, busts, &c. which when dry will take a high polish, and prove very durable. It has been said that the Chinese use it for quadrille fish and other articles, which may be mistaken for mother of pearl; but this account has been proved erroneous.

Cements for Turners, &c.

One pound of rosin, and four ounces of pitch, melted together, and while boiling hot, stiffened by the addition of brick-

dust, make a strong cement for cementing pieces of work to chucks. The brick-dust may be added in small quantities, and after mixing it each time, a drop or two of the cement may be taken out, and allowed to cool, to prove whether it is hard enough. It may be poured into water, and made up in rolls to be kept for use.

Four ounces of rosin, a quarter of an ounce of wax, and four ounces of whiting or any kind of ochre, form a finer cement of the same kind as the above.

Pitch, stiffened merely by the addition of wood ashes, is often used by glass-grinders.

Any of these cements, when required to be particularly tough, and to cement any thing which has to sustain the blow of a hammer, as articles that are cut with a punch, may be mixed up with a little tow. They may also at any time be made softer by melting them with more or less tallow.

Potato Size.

Size is a much diluted cement, and is either prepared from common glue, or isinglass, or by boiling the shreds of parchment or white leather, or consists of flour paste made very thin; but these compositions, particularly those of an animal nature, quickly putrefy, and produce a disagreeable smell, from which potato size is free. The potatoes must be grated into water, and after changing the water once or twice, there will be found at the bottom of the vessel a white fecula or starch. This starch is made into size, by boiling it with a sufficient quantity of water. Mingled with whitewash, an excellent and durable white is formed, which will not rub off.

Cement withstanding Sulphuric Acid.

Chaptal had occasion for a cement, in his experiments to make alum, from its constituent principles, which would not grow soft or crack with a heat from 122 to 144 of Fahrenheit, which should withstand the sulphuric acid, and which should be so smooth that no cracks or crevices should appear on its surface. He at length, after a series of experiments that continued from 12 to 15 months, found that equal parts of rosin, turpentine, and wax, answered best. These three substances are melted together in a pot; and when all the volatile oil which causes the mixture to rise is dissipated, it is to be applied boiling hot with a brush.

The number of uses to which this cement may be applied is very great. It may be employed to line the casks used on

board a ship; the water or victuals kept in them would not be so subject to grow putrid, even the ships themselves might be coated with it. This cement is preferable to tar in many respects; it is not so subject to crack, it is less sticky, more supple, and has a smoother surface. A board six feet long, and 18 inches wide, covered with it, was kept in water for 19 months. It had not imbibed any water, nor was the coating at all damaged If it should be required to render it more consistent, powdered bricks may be used.—*Rep.* vol. 2.

LUTES.

Lutes are compositions which are employed to defend glass and other vessels from the action of fire, or to fill up the vacancies which occur when separate tubes, for the necks of different vessels, are inserted into each other, during the process of distillation. Those lutes which are exposed to the action of the fire, are usually called *fire lutes.*

For a very excellent fire lute, which will enable glass vessels to sustain an incredible degree of heat, take fragments of porcelain, pulverise and sift them well, and add an equal quantity of pure clay, previously softened with as much of a saturated solution of muriate of soda, as is requsite to give the whole a proper consistence. Apply a thin and uniform coat of this composition to the glass vessels, and allow it to dry slowly before they are put into the fire.

Equal parts of coarse sand and refractory clay, mixed with a little hair, form a good fire lute.

Fat earth, beaten up with fresh horse dung, Chaptal recommends as an excellent fire lute, which he generally used, and the adhesion of which was such, that after the retort had cracked, the distillation could be carried on and regularly finished.

Lutes for the joining of such vessels as retorts and receivers, are varied according to the nature of the vapours which will act against them, in order not to employ a more expensive and troublesome composition than the case requires. For resisting watery vapours, slips of wet bladder, or slips of paper or linen, covered with stiff flour paste, may be bound over the juncture.

A closer and neater lute for more penetrating vapours, is composed of whites of eggs made into a smooth paste with quicklime, and applied upon strips of linen. The quicklime should be previously slacked in the air, and reduced to a fine

powder. The cement should be applied the moment it is made; it soon dries, becomes very firm; and is in chemical experiments one of the most useful cements known.

Where saline, acrid vapours are to be resisted, a lute should be composed of boiled linsed oil intimately mixed with clay, which has been previously dried, finely powdered, and sifted. This is called fat lute. It is applied to the junctures, as the undermost layer, and secured in its place by the white of egg lute last mentioned, which is tied on with packthread.

VARNISHES.

To dissolve Copal in Alcohol.

Copal, which is called gum copal, but which is not strictly either a gum or a resin, is the hardest and least changeable of all substances adapted to form varnishes, by their solution in spirit, or essential or fat oils. It therefore forms the most valuable varnishes, though we shall give several recipes where it is not employed, which form cheaper varnishes sufficiently good for many purposes, adding only the general rule, that no varnish must be expected to be harder than the substance from which it is made.

To dissolve copal in alcohol, dissolve half an ounce of camphor in a pint of alcohol; put it into a circulating glass, and add four ounces of copal in small pieces; set it in a sand heat, so regulated that the bubbles may be counted as they rise from the bottom; and continue the same heat till the solution is completed.

The process above described, will dissolve more copal than the menstruum will retain when cold. The most economical method will therefore be, to set the vessel which contains the solution by for a few days, and when it is perfectly settled, pour off the clear varnish, and leave the residuum for a future operation.

The solution of copal thus obtained is very bright: it is an excellent varnish for pictures; and would doubtless be an improvement in japanning, where the stoves used for drying the varnished articles would drive off the camphor, and leave the copal clear and colourless on the work.

To dissolve Copal in Spirits of Turpentine.

Reduce two ounces of copal to small pieces, and put them into a proper vessel. Mix a pint of the best spirits of turpentine with one eighth of spirit of sal ammoniac; shake them well together, put them to the copal, cork the glass, and tie it over with a string or wire, making a small hole through the cork. Set the glass in a sand heat, so regulated as to make the contents boil as quickly as possible, but so gently that the bubbles may be counted as they rise from the bottom. The same heat must be kept up exactly till the solution is complete.

It requires the most accurate attention to succeed in this operation. After the spirits are mixed, they should be put to the copal, and the necessary degree of heat be given as soon as possible, and maintained with the utmost regularity. If the heat abates, or the spirits boil quicker than is directed, the solution will immediately stop, and it will afterwards be in vain to proceed with the same materials; but if properly managed, the spirit of sal ammoniac will be seen gradually to descend from the mixture, and attack the copal, which swells and dissolves, excepting a very small quantity which remains undissolved.

It is of much consequence that the vessel should not be opened till some time after it has been perfectly cold; for if it contain the least warmth when opened, the whole contents will be blown out of the vessel.

Whatever quantity is to be dissolved, should be put into a glass vessel capable of containing at least four times as much, and it should be high in proportion to its breadth.

This varnish is of a rich deep colour, when viewed in the bottle, but seems to give no colour to the pictures upon which it is laid. If it be left in the damp, it remains sacky, as it is called, a long time; but if kept in a warm room, or placed in the sun, it dries as well as any other turpentine-varnish, and when dry it appears to be as durable as any other solution of copal.

Copal may also be dissolved in spirits of turpentine by the assistance of camphor.

Turpentine varnishes dry more slowly than those made with alcohol, and are less hard, but they are not so liable to crack.

To dissolve Copal in fixed Oil.

Melt in a perfectly clean vessel, by a very slow heat, one pound of clear copal; to this add from one to two quarts of drying linseed oil. When these ingredients are thoroughly mixed, remove the vessel from the fire, and keep constantly

stirring it, till nearly cold; then add a pound of spirits of turpentine. Strain the varnish through a piece of close linen, and keep it for use. The older it is, the more drying it becomes.

This varnish is very proper for wood-work, house and coach painting.

Seed-lac Varnish.

Take three ounces of seed-lac, and put it with a pint of spirits of wine into a bottle, of which it will not fill above two-thirds. Shake the mixture well together, and place it in a gentle heat, till the seed-lac appears to be dissolved: the solution will be hastened by shaking the bottle occasionally. After it has stood some time, pour off the clear part, and keep it for use in a well stopped bottle. The seed-lac should be purified before it is used, by washing it in cold water, and it should be in coarse powder, when added to the spirit.

This varnish is next to that of copal in hardness, and has a reddish yellow colour: it is therefore only to be used where a tinge of that kind is not injurious.

Shell-lac Varnish.

Take five ounces of the best shell-lac, reduce it to a gross powder, and put it into a bottle that will hold about three pints or two quarts. Add to it one quart of rectified spirits of wine, and place the bottle in a gentle heat, or a warm close apartment, where it must continue two or three days, but should be frequently well shaken. The lac will then be dissolved, and the solution should be filtered through a flannel bag; and when the portion that will pass through freely is come off, it should be kept for use in well-stopped bottles. The portion which can only be made to pass through the bag by pressure, may be reserved for coarse purposes.

Shell-lac varnish is rather softer than seed-lac varnish, but it is the best of all varnishes for mixing with colours to paint with instead of oil-colours, from its working and spreading better in the pencil.

Varnish for Toys, silvered Clock-faces, and Furniture not exposed to hardship.

Dissolve two ounces of gum-mastic, and eight ounces of gum-sandrach, in a quart of alcohol; then add four ounces of Venice

turpentine. The addition of a little of the whitest part of gum-benjamin will render the varnish less liable to crack.

Amber Varnish

Amber forms a very excellent varnish; its solution may be effected by boiling it in drying linseed oil.

Oil varnishes which have become thick by keeping, are made thinner with spirits of turpentine.

JAPANNING.

Japanning is the art of varnishing in colours, and is frequently combined with painting.

The substances proper for japanning, are, wood and metal, with all others which retain a determinate form, and are capable of sustaining the operation of drying the varnish. Paper and leather, therefore, when wrought into forms in which they remain stretched, stiff, and inflexible, are very common subjects for japanning.

The article to be japanned is first rendered smooth and perfectly clean, it is then brushed over with two or thee coats of seed-lac varnish, prepared as above directed, (p. 792,) except that the coarsest seed-lac will answer the purpose. The varnish thus laid on is called the *priming*. The next operation is to varnish the article again with the best varnish previously mixed with a pigment of the tint desired. This is called the *ground-colour;* if the subject is to exhibit any painting, the objects are painted upon it, in colours mixed up with varnish, and used in the same manner as for oil-painting. The whole is then covered with additional coats of transparent varnish, and all that remains to be done, is to dry and polish it.

Japanning should always be executed in warm apartments, as cold or moisture are alike injurious; and all the articles should be warmed before any varnish is applied to them. One coat of

varnish, also, must be dry before another is laid on. Ovens are employed to hasten the perfect drying of the work.

All the coloured pigments employed in oil or water, answer perfectly well in varnish, combined with which vehicle, many of those which fly in oil, are perfectly unchangeable. The manner in which the colours are mixed with the varnish is extremely simple and easy: they are first reduced, by the usual means of washing and levigation, to the finest state possible; and the varnish being contained in a bottle, they are added to it, till the requisite body of colour is obtained; the mixture being rendered complete by stirring or shaking the bottle. When a single colour is intended, the varnish employed is of no consequence, if it be hard enough for the work, and not possessed of any colour inconsistent with the tint required; but for painting with, shell-lac varnish is the best, and easiest to work: it is therefore employed in all cases where its colour permits, and for the lightest colours, mastic varnish is employed, unless the fineness of the work admits the use of copal dissolved in spirits of wine.

To spare varnish, the priming may be composed of size mixed with whiting, to give it a body, as some substances require much varnish to saturate them; but work primed with size is never durable; it is liable to crack and fly with the least violence, which never happens to work into which the varnish can sink. Varnish cannot sink into metals, and this is the reason that japanned metal, for example a japanned tin-plate tray, is of less value than a paper one. The battering which this piece of furniture sustains in its use, soon separates the japan from it in flakes, or scales; which never happens to the paper, because the japan forms a part of its substance.

It may be observed, that only wood, paper, leather, and similar substances, require priming: metals require none, because they admit no varnish into them; and therefore the ground is applied to them immediately.

The priming and grounds are all laid on with brushes made of bristles: the painting will of course often require camel's-hair pencils.

Of Japan Grounds.

Red.—Vermilion makes a fine scarlet, but its appearance in japanned work is much improved by glazing it with a thin coat of lake, or even rose-pink.

Indian lake, when good, is perfectly soluble in spirits of wine, and produces a fine crimson, but is not often to be obtained.

Yellow.—King's yellow, turbith mineral, and Dutch pink, all form very bright yellows, and the latter is very cheap. Seed-lac varnish assimilates with yellows extremely well; and where they are required very bright, an improvement may be effected by infusing turmeric in the varnish which covers the ground.

Green.—Distilled verdigris laid on a ground of leaf gold, produces the brightest of all greens; other greens may be formed by mixing king's yellow and bright Prussian blue, or turbith mineral and Prussian blue, or Dutch pink and verdigris.

Blue.—Prussian blue, or verditer glazed with Prussian blue or smalt.

White.—White grounds are obtained with greater difficulty than any other. One of the best is prepared by grinding up flake-white, or zinc-white, with one-sixth of its weight of starch, and drying it; it is then tempered, like the other colours, using the mastic varnish for common uses; and that of the best copal for the finest. Particular care should be taken, that the copal for this use be made of the clearest and whitest pieces. Seed-lac may be used as the uppermost coat, where a very delicate white is not required, taking care to use such as is least coloured.

Black.—Ivory-black or lamp-black; but if the lamp-black be used, it should be previously calcined in a closed crucible.

Black grounds may be formed on metal, by drying linseed oil only, when mixed with a little lamp-black. The work is then exposed in a stove to a heat which will render the oil black. The heat should be low at first, and increased very gradually, or it will blister. This kind of japan requires no polishing. It is extensively used for defending articles of ironmongery from rust.

Tortoise-shell ground for metal.—Cover the places intended to represent the transparent parts of the tortoise-shell, with a thin coat of vermilion in seed-lac varnish. Then brush over the whole with a varnish composed of linseed oil boiled with umber until it has an almost black colour. The varnish may be thinned with oil of turpentine before it is used. When the work is done, it may be set in an oven, with the same precautions as the black varnish last named.

Polishing of varnished and japanned Work.

Pictures and other subjects, to which only a single coat or two of thin varnish is given, are generally left to the polish which the varnish naturally possesses, or brightened only by rubbing it with a woollen cloth, after it is dry; but wherever several coats of varnish or japan are laid on, a glossy surface is produced by the means used to polish metals; the surface having first been suffered to become completely dry and hard.

Where the coat of varnish is very thick, the surface may be rubbed with pumice-stone and oil, till it becomes uniformly smooth; the pumice should first be reduced to a smooth flat face by rubbing it on a piece of freestone. The japanned or varnished surface may afterwards be rubbed with pumice reduced to an impalpable powder, by pounding and washing over, using oil and a rag or leather to lay on the powder. The finishing may be given by oil and a woollen rag only.

Where the varnish is thinner, and of a more delicate nature, it may be rubbed with tripoli or rotten-stone, in fine powder, finishing with oil as before. Where the ground is white, putty or Spanish white, finely washed, may be used instead of rotten-stone, of which the colour might have some tendency to injure the ground.

Preparation of Drying Linseed Oil.

Frequent references having been made, in the arts of varnishing and japanning, to the use of drying oil, it may be necessary to observe, that to render linseed oil drying, consists simply in mixing it with litharge, or any oxide of lead, boiling it slowly for some time, and straining it from the sediment, after it has stood to clarify. The oil thus treated, becomes thicker as it imbibes oxygen from the oxide, and acquires the property of drying much sooner than before. An ounce of litharge may be used to every pound of oil.

LACQUERING.

*Lacquering is the application of transparent varnishes to metals, to prevent their tarnishing, or to give them a more agreeable colour.

When the colour of the metal to be lacquered is to be changed, the varnish is tinged with some colouring matter; but where preservation from rust or tarnish is the sole object, any of the transparent varnishes already described will answer, using the best and hardest where the greatest durability is required.

Lacquer to imitate Gilding.

Take eight ounces of amber, and two ounces of gum-lac, melt them in separate vessels, and mix them well together; then add half a pound of drying linseed oil. Into a pint phial, put half a pint of spirits of turpentine, and digest in it a little saffron; when the colour is extracted, strain the liquor, and add gum-tragacanth and annotta, finely powdered, and in small quantities at a time, till the required tone of colour is produced; then mix this colouring matter with the above ingredients, and shake them well together, till a perfect union takes place.

If this varnish be laid over silver leaf or tin-foil, it will be difficult to distinguish it by the eye from gold. It is by a varnish of this kind, that leather, paper, or wood, covered with silver leaf, is made to appear as if it were gilded. The lacquer is also applicable to tin-plate articles, but small articles of finely polished brass, are usually coated with a thinner composition.

A Lacquer for Tin or Brass.

Infuse one ounce of turmeric root, and two drachms of gum-tragacanth, in a pint of spirits of wine, and keep the mixture in a warm place for some days, frequently shaking it. Use this composition to strengthen the colour of seed-lac varnish, which may then be applied to the tin. The colour may be made weaker or stronger by using more or less gum-trgacanth.

Achorid, or yellow Botany Bay gum, which may sometimes be had at the druggists, makes a good lacquer for tin or brass, by dissolving it in spirits of wine without heat. The achorid in drops is the best.

GILDING.

The processes of gilding are very various, but the principles upon which the gold is caused to adhere to the surfaces upon which it is applied, may be reduced to two; viz. chemical affinity, and the use of cements. All solid bodies may be gilt upon the latter principle, using thin leaves of gold; but metals only admit of the former, which is generally applied to them, because it is much more perfect than the other, and equally as easy to execute.

Gilding of Metals by Amalgamation.

Eight parts of gold and one of mercury are formed into an amalgam by using the gold in thin plates, making it red hot, and then putting it into the mercury which has been previously heated to ebullition. The gold immediately disappears, and combines with the mercury; the mixture is poured into cold water, and is ready for use. This amalgam is chiefly employed to gild copper and brass in the following manner: The article to be gilt is rubbed over with much diluted nitric acid, to remove any tarnish or rust which would prevent the amalgam from adhering. If a little mercury be dissolved in the nitric acid thus used, it facilitates the subsequent part of the process. The amalgam is applied to the piece by means of a brass wire brush, in as even a manner as possible. The piece is then set upon a grate over a fire, or into an oven heated to a degree at which mercury exhales. By this means the gold is left alone, and the defects which are observed in the piece after the first application, are rectified by repetitions of the process. After

the mercury has evaporated, the gold has only a dull yellow colour. To change this, it is brushed with the scratch brush, (made of brass wire,) till it has a smooth surface: it is then covered with gilding-wax, and exposed to the fire till the wax is burnt off. This wax is composed of four ounces of bee's wax, one ounce of acetate of copper, and one ounce of sulphate of copper. It heightens the colour a little, but a further improvement is effected, by covering it with a paste made of nitre and alum, mixed up with water or urine. It is then heated again, and suddenly plunged into cold water. The finishing operation is to burnish the piece with a blood-stone or steel burnisher.

Gilding by amalgamation in the large way, is extremely injurious to the workmen, on account of the fumes of mercury which they cannot avoid receiving into the system; but it may be practised in a single experiment or two without any harm resulting.

Cold Gilding of Silver.

Dissolve gold in the nitro-muriatic acid, and dip some fine linen rags into the solution; then burn the rags, in the manner that tinder is prepared, by first drying it, and then setting it on fire, and preserve the ashes. The silver to be gilt, must have a clean, burnished surface; and after having been rubbed with a solution of salt in water, it must be rubbed with the black powder or ashes, which may be taken up and laid on with a cork. The work is finished by burnishing.

Gilding of Brass and Copper.

Mathematical and other fine instruments made of brass, are generally gilt, as gilding is a much neater and more durable method of preserving them from tarnishing, than any kind of varnish or lacquer.

For this purpose, saturate nitro-muriatic acid with gold, and having evaporated the solution to an oily consistence, suffer it to crystallize. Dissolve these crystals in pure water, and dip into this watery solution of gold the articles which require to be gilt, which should have perfectly clean and polished surfaces; the finish is given by burnishing. The gilding may be made strong, by a frequent repetition of the process. It is advisable to use the solution of the chrystals in water, instead

of the nitro-muriatic solution, in order to prevent the intervention of any acid, which would injure the brass or copper.

Gilding of Iron and Steel.

The surface of the iron being first well polished, it must be heated till it becomes blue, when gold leaf must be applied to its surface and burnished down. It must then be heated again, and another layer of gold burnished on. This process must be repeated three or four times, according to the strength of the gilding required.

Another much more easy and elegant mode of gilding iron and steel, is the following. To a nitro-muriatic solution of gold, add about twice the quantity of sulphuric ether. The mixture must be made with caution, and in a large vessel. The liquids being shaken together, are to be left till they separate from each other, which will shortly take place, and the ether will float on the surface of the acid. The colour of the acid will have become brighter, that of the ether darker than before; because the ether has taken up the gold which the acid held in solution. The ether may be drawn off by a siphon; or pour the two fluids into a glass funnel, the pipe of which is stopped at the bottom, and when they have again separated as before, the aperture may be opened, and the whole of the acid allowed to run off. The auriferous ether will thus be obtained alone, and must be kept for use in bottles with air-tight stoppers.

Well polished articles of iron or steel may at any time be instantly gilt by dipping them into this ariferous ether, or by spreading the ether over them with a brush. Even a pen or pencil dipped in the ether may be employed to write or draw with, and the figures delineated will be beautifully gilded on the iron.

The essential oils of turpentine and lavender will take up the solution of gold in the same manner as ether.

OF OIL GILDING, BURNISH GILDING, AND JAPANNERS' GILDING.

In these methods of gilding, leaf gold is employed; they are applicable to all substances that require gilding, though metals, as shewn above, can be better gilt by methods adapted to their peculiar nature. They are therefore chiefly employed for wood, paper, and leather.

The leaf gold which is manufactured for gilding, is of two qualities, viz. *pale gold* and *deep gold*. Pale gold contains a considerable proportion of silver, and tends to the colour of that metal. It is sometimes useful, by way of variety in japanning. Deep gold is the purest metal, and the richest in its colour.

Dutch gold, which consists almost entirely of copper, very soon tarnishes when exposed to the air; and should not, even when varnished, be used for any valuable purpose. As it is, however, scarcely a twelfth part of the value of true gold leaf, it is occasionally useful where large quantities of gilding are required for temporary purposes. It is used in the same manner as true gold.

The instruments used in gilding are the following:

A *cushion*, on to which the gold is taken from the books in which it is purchased, and cut to the size required, and laid out ready for taking up. It consists of a board of any convenient size, on which is laid two thicknesses of flannel, and covered with calf-skin, such as bookbinders use, with the rough or flesh side uppermost.

A *knife*, with which the gold is taken out of the book, and cut upon the cushion to the required size. It should be like a pallet-knife, and should have a smooth edge, though not very sharp. If in good order, the gold may be cut with it into strips not the tenth of an inch in breadth, without jagging, and without cutting the cushion. The gold is cut by gently pressing upon it, with a short reciprocating motion like that in using a saw.

The *tip*, which consists of a squirrel's tail with the hairs cut short. It is used for taking up whole leaves of gold, and applying them to the surface to be gilt. In order that it may take up the gold, it is moistened in some degree by breathing

upon it. A piece of strong writing paper, rubbed upon the skin of the face, or even upon the hair, may be used to take up leaves of gold.

Some loose cotton-wool is employed to press down the leaf which has been laid on, and to take up small pieces.

A large camel's-hair brush, is used for dusting the work, and taking off the superfluous gold when it is dry.

Oil Gilding.

The first operation is to prime the work, with a mixture of white lead and drying linseed oil. When the priming is dry, a thin coat of gold size is laid on the work, composed of stone ochre ground in fat oil; when this first coat is dry, a second is laid on for the best work, but in general one coat is made to suffice. When the gold size is so far dried that though it will not daub the fingers, it feels clammy, it is fit for gilding upon. The leaf gold is therefore taken up and laid upon it with the tip, pressed down with cotton-wool, and when every part of the surface is covered, it is left in a warm place to dry, and finished by brushing off the loose pieces of gold.

This kind of gilding is easily performed, and stands the weather well. It has no lustre, but that is for some purposes esteemed an excellence.

Burnish Gilding.

This kind of gilding is much employed for wood. The surface to be gilt is first made clean and smooth, it is then primed with a mixture of whiting and size, prepared by boiling parchment or white leather in water, till, when cold, it has the consistence of a jelly, Seven or eight coats of this composition are laid on. After the last coat is dry, the mouldings, if any, must be restored, by the use of proper tools, to the sharpness they are required to possess, and the parts intended to be burnished should be polished by rubbing them with a linen rag moistened with water. The whole is then to receive two coats of gilding size, which consists of parchment or white leather size, combined with a little Armenian bole. When the last of these coats is dry, the parts intended to be burnished are again rubbed smooth with a linen rag. A part of the work must now be wetted with water by means of a camel's-hair pencil and before this becomes dry, the gold leaf must be

applied as in oil-gilding; and thus proceeding by wetting no more at a time than can be gilded before the water dries, the work is continued till it is finished. The repairs required should be done as the work goes on, so that none of the imperfections may require fresh size; and care should be taken to prevent the water from running over any of the gold which has been laid on.

When the work has become firm, it should be burnished; this is done with the least labour, and imparts the highest lustre, when the surface is in a state little short of perfect dryness. The best burnishers are made of agate; the next of dog's tooth; steel may serve if very hard and highly polished, but it is apt to produce mischievous effects, by rubbing up the gold, if it acquire the least rust, or is not used with a very slow and careful motion.

Deep mouldings and other parts, which cannot be gilt, and which are not intended to appear neglected, are usually coloured with Dutch pink, or some other yellow, mixed up with size.

Japanner's Gilding.

The figures or parts intended to be gilt, must be coated with gold size by means of a hair pencil; the leaf gold is then applied as in the above modes of gilding, and after it is dry, the superfluous parts are brushed off.

The gold size is prepared in the following manner; take one pound of linseed oil and four ounces of gum animi. Set the oil to boil in a proper vessel, and then add the gum animi gradually in powder, stirring the oil all the time, and not adding a second quantity till the former appears to be dissolved. Let the mixture continue to boil, till, on taking a small quantity out, it appears of a thicker consistence than tar, then strain the whole through a coarse cloth, and keep it for use. When it is wanted it is ground with vermillion, and diluted with spirits of turpentine to the consistence proper for working. This gold size may be employed for gilding surfaces of almost every kind.

When great brilliancy is not wanted, shell gold may be used instead of gold leaf, to gild upon the size.

Gilding of Paper and Leather.

Letters written with ink containing a large proportion of gum arabic, if breathed upon, and gold leaf immediately

applied, will retain the gold, wherever the pen has marked, and the remainder of the leaf may be brushed off. Or letters may be formed with the shell-gold, prepared as directed below.

The edges of paper and books are gilded with a size composed of whites of eggs beaten up with three or four times their quantity of water, and mixed with a little Armenian bole.

The bookbinders gild the leather of books, by coating the leather two or three times with whites of eggs, well beaten up, but not mixed with water. When the last coat is dry, they rub a very minute quantity of tallow over the leather, and then cover it with gold leaf. The stamps or letters which they require, are cut in brass in the manner of printing types; these being heated just so much as the leather will bear without shrivelling, they press them gently upon the gold leaf, which thus becomes fixed in every part touched by the stamp, and the useless gold is rubbed off with a linen rag. The tallow is used merely to make the gold come off freely, where the stamp makes no impression. The due heat of the stamp can only be determined by experience; it differs a little with the texture of the leather.

Gilding of Porcelain and Glass.

Draw the design with the japanner's gold size, prepared as above directed; set it near the fire or in an oven, for a few minutes, or till it becomes of such a warmth that it can just be held in the hand; then apply the gold leaf, after which put the vessel into an oven, and let it remain there for two or three hours at the least; when dry, it may be burnished.

The most durable method of gilding glass or porcelain, is by burning in: for this purpose, dissolve gold in nitro-muriatic acid, and precipitate it by putting copper into the acid. Mix this precipitate with a strong solution of borax and gum-water, and when the design is drawn with it, the gold will be fixed by burning in, as in painting on glass.

Preparation of Shell Gold.

Grind gold leaf with pure honey, until it appears to be completely divided among the honey; then wash away the honey with water, and mix the gold powder with gum-water. The gold thus prepared, may be applied to any surface in the

same manner as a colour, and forms at once a very tolerable gilding.

Preparation of the fat Oil used in Gilding.

Take any vessel having a considerable surface, and fill it to the depth of six inches with water; then pour in as much linseed oil as will, when it has risen to the surface, form a layer of about an inch in thickness. Expose the oil, thus circumstanced, to the action of the sun and air, until it assumes nearly the consistence of treacle, which in summer will require five or six weeks. Then draw off the oil into a tall bottle, and set it in a warm place, till it becomes perfectly fluid, when it may be poured off from the water and foulness, which will subside, and after being strained through a flannel, may be kept for use.

SILVERING.

Wood, paper, and all similar substances, are silvered in the same manner as they are gilded, by substituting silver leaf fo gold leaf; and using whiting only, instead of Armenian bole or ochre, to mix with the size forming the ground. Silvered surfaces are sometimes made to resemble gold leaf by lacquering them.

To silver Copper and Brass.

Dissolve silver in nitric acid, by the assistance of heat; put some pieces of copper into the solution, and the silver will be precipitated. With fifteen or twenty grains, of the precipitate thus obtained, mix two drachms of tartar, the like quantity of common salt, and half a drachm of alum. With this mixture rub the clean surface of copper till it becomes white, and then finish it by polishing with leather. The surface of the copper is usually cleansed, by washing it with much diluted nitric acid, before the mixture is applied.

Copper may also be silvered by dipping it into a weak solution of mercury in nitric acid; then rubbing it with the preci-

pitate above mentioned and common salt. Dial-plates may be silvered in this manner; and the silvering may be strengthened when there is occasion, by heating it, till the mercury is driven off, and the silver united by fusion to the metal, then repeating the process. Dial-plates are usually preserved by a coat of transparent varnish.

Copper may also be silvered by heating it, and burnishing silver leaf upon it, till a sufficient coat is given. This is called French plate, and is very flimsy.

To silver Ivory.

Immerse the ivory in a weak solution of nitrate of silver, till its colour appears to be a bright yellow; take the ivory out of the solution, and expose it, under water, to the rays of the sun. In two or three hours it becomes black; but the blackness changes to the colour of silver, by taking it out of the water and rubbing it.

To prepare Shell-Silver

Shell silver is prepared in exactly the same manner as shell gold, see page 804.

To silver Plane Mirrors.

In silvering mirrors, no silver is employed; the composition with which they are coated at the back consists of an amalgam of mercury and plates of tin called tin-foil.

Upon a horizontal table of stone, perfectly smooth and level, lay down some paper, a little larger than the glass to be silvered; dust evenly upon it some finely-washed whiting, and upon the whiting lay down tin-foil, also a little larger than the glass. Holding the tin-foil by one end, brush it over gently with a hair's foot or a piece of cotton wool, to make it lie close. Pour a small quantity of mercury upon the tin, and spread it evenly over the whole surface with the hair's foot: then pour on a larger quantity of mercury, and spread it evenly in like manner. Place a sheet of paper upon the mercury, and make it touch in every part by the hair's foot; then laying the plate even with one edge of the paper, carry it over the whole surface, gently touching the paper as it advances, and place it

exactly over the middle of the tin foil. Gently draw out the paper next to the glass, without lifting up the glass, though when it is heavy, it will be necessary to relieve its pressure. Place several thicknesses of paper upon the glass, and upon these let considerable weights be distributed over the whole surface. In a day or two the amalgam will have become firm, and adhering perfectly to the glass, when the weights may be removed, and the looking-glass is ready for framing.

The paper employed between the amalgam and the glass, should be thin, smooth, and entirely free from knots. Its use is to assist in obtaining the contact of the mercury and the glass, without air-bubbles or raising the foil. It might be dispensed with by bringing the glass horizontally over the mercury, and driving some of the mercury before it, but there would be more risk of injuring the foil by accident.

The surface of the glass should be perfectly clean, and freed especially from grease.

The stone table should be surrounded with a groove to retain the superfluous mercury.

To Silver convex and concave Mirrors.

Surround the glass with a border, two or three inches high, made of several folds of stiff paper, or of pasteboard; then pour upon its convex side a mixture of plaster of Paris and water. When the plaster has hardened, which will be in about half an hour, the border may be taken off, and the glass separated; and to render this more easy, it should be rubbed over with an oily cloth before the plaster is poured on. Then cast a similar mould in the concave side of the glass. These moulds will be dry in two or three days; by spreading tin-foil on the concave one, the convex side of a glass may be silvered, or by spreading it on the convex mould, the concave side of the glass may be silvered. In either case, the spare mould being put on the glass serves as the means of applying the requisite weight in an even manner. The paper employed in silvering plane mirrors must be omitted, and in silvering the concave side, a border of paper should surround the plaster, to retain the mercury till the glass has been put down, when it may be removed, or a hole made in the border to let the mercury run off.

To silver Glass Globes.

Take equal quantities of tin and lead, and melt them together; when they are fluid, add to them two parts of bismuth; take the mixture from the fire, and before it hardens add to it two parts of mercury, and stir the whole till united. As soon as the mass becomes cool enough for the glass to bear, pour it into the globe by means of a funnel. Then move the globe slowly, in such a manner that the amalgam may touch every part of its interior. If it have the proper tenacity, it will leave a thin film of its substance adhering to every part of the glass which it touches; when not sufficiently fluid to do this, the fault may be remedied by warmth: when too fluid, the amalgam must be taken out, and some more tin, lead, and bismuth, must be added to it.

MOULDING AND CASTING IN PLASTER.

The greatest difficulty which presents itself in this art, to young practitioners, arises from the want of good plaster, of which both the moulds and the casts themselves are made. The plasterers, marble-masons, and other artisans who use this article, make it answer their purpose in a state so inferior to that in which it may be obtained, and so variable, too, in its properties, that the use of it, as prepared for them, is certain to occasion an immensity of trouble and disappointment. We shall therefore give directions for obtaining plaster in perfection, and the operator will find the recipe of infinitely more consequence to him, than all the general instructions which can be given in relation to other branches of the subject.

Preparation of Plaster of Paris.

Take any quantity of finely-powdered gypsum, which is the name of plaster of Paris in its raw state, and put it into an iron pan or boiler, which may be filled to within a few inches of the

brim. Set the boiler upon a good fire, and stir the powder with a rake, to heat it uniformly. When the powder becomes hot, bubbles will rise to its surface, and it will have all the appearance of a fluid. The boiling must be continued till the bubbling ceases; the operation is then finished, and nothing more is required than to cover the boiler with a lid, and to allow the plaster to cool gradually, in a warm place, by removing it to one side of the fire, suffering the fire to die out.

The plaster thus prepared may be depended on; when mixed with water to the consistence of cream, and poured upon any figure, it hardens in a few minutes, and takes a very sharp impression: by gradual drying, it afterwards acquires almost the hardness of stone. Drying in an oven, although necessary for some purposes, inevitably renders all plaster tender; but after having been prepared as above directed, it will have a considerable degree of cohesion, when other kinds, heated in the same manner, will drop to powder under the slightest pressure.

When plaster is not used immediately after it is made, it should be kept in air-tight casks; for it may be regarded as a species of quicklime; and the longer it is suffered to absorb the moisture which it greedily takes from the atmosphere, the more it is injured.

Plaster is usually prepared by calcining lumps of gypsum in an oven, and though some care may be taken to have the lumps nearly of a size, it is plain there can be no such thing in the usual routine of this business, with common labourers, as heating it uniformly and to the just degree, nor of suffering a due portion of water to escape from every particle alike: by too much heat, the sulphuric acid may in a great measure be driven from it, and then it can be of little value; when cold, it is taken to be ground, during which operation it is leisurely exposed to the atmosphere; it is then, like wheaten flour, kept in open bins for sale. Thus it appears that in every step of the ordinary mode of preparing and managing plaster, its properties are deteriorated; without a word of reference to the adulterations frequently practised.

When the plaster is required for very delicate purposes, it should be sifted before it is used, but not otherwise, if it have been well ground. The sifting is performed with so much rapidity, that the exposure to the air which the plaster receives during the process, cannot sensibly hurt it: it may be sifted before it is boiled, but not so quickly as afterwards, because it clogs the sieve.

Gypsum, or raw plaster, exists in inexhaustible quantities in Derbyshire, Westmoreland, and some other counties. It

may generally be bought in the state of stone, of those who manufacture it, and sometimes those persons who prepare and sell it in the ordinary way will undertake to grind it raw. If, however, the stone can be obtained, a small quantity may be formed by pounding in a mortar; but almost every village will afford some means or other of reducing it to powder by machinery, where the demand may be considerable.

Of Moulding.

A mould is the impression of any subject taken in some plastic substance, for the purpose of forming the resemblance of that subject, by filling its hollows with a suitable material, and then separating the casting from it. The original subject may either itself be a cast, or the product of manual labour. The manner in which a mould of it is made, depends very much upon its form. Supposing it to be a simple bass-relief, like a coin, it is obvious that any substance poured upon it will separate easily, if there be no cohesion between the two surfaces: therefore to mould such a subject, it is necessary to surround it with an edging, which should be sufficiently high to allow a proper strength for the mould. The surface of the subject being slightly coated with oil, the plaster must be mixed with water, and instantly poured on to the requisite depth. When the plaster has acquired the hardness of bee's wax, the border may be taken off, and the original separated by drawing it evenly from the mould.

The mould thus obtained, is allowed gradually to dry, and being soaked with tallow or oil, any number of casts, like the original, may be made with it. If lead or any other metal is intended to be cast in the mould, it must be dried in an oven, that every particle of moisture may be evaporated, to prevent the hazard of an explosion.

When there are undercuttings in the bass-relief, so that the plaster poured upon it would run into cavities, from which it could not be drawn up, but would break in them, these undercuttings must be filled up with plaster, from which, when it is dry, and has been made smooth, the plaster poured on to form the mould, will easily separate. Then when the casts have been made from the mould, they are finished by restoring the undercuttings with proper tools.

Where the original subject or model is a bust, or any complex figure of that nature, after it has been oiled in every part, the plaster is mixed up to the consistence of paste, and immediately applied to it with the hands. After it is dry, it is

divided by a very thin-bladed knife, and taken off in such portions as will separate perfectly from the original; the adjoining parts are marked, so that they can easily be put together in their proper order. When the different parts have been dried and oiled, and are completely put together again, plaster is poured into the interior of the mould thus prepared by means of a small aperture, and the mould is turned in every direction, so that the plaster may adhere to every part within it, and when a sufficient quantity of plaster is poured in to produce the strength required in the cast, the remainder is left hollow, both for the sake of lightness, and to save expense in plaster. When the cast is dry, it is extricated by separating the pieces of which the mould is composed, and it is finished, where it appears to require it, with chisels or any similar tools.

The above is the usual process; but as layers of fluid plaster laid one over another, are weaker considerably than when the whole is poured in at once, the part intended to be left hollow may be filled with a core, which may be a piece of wood, when the figure of the hollow part designed to be left will be such that the wood can be drawn out; or when this is not the case, the core may be of clay, which is easily retained in its place by wires from the mouth of the aperture; the clay may be picked out when the cast is perfectly hardened.

Casts from the faces of living persons are frequently taken in plaster: the hair is tied back, the eyes are closed, a hollow roll of paper is put up each nostril to breathe through, and the skin is anointed with salad oil: the newest and best plaster being used, it sets and may be separated in a few minutes.

Plaster moulds in which metals are designed to be run, should contain an admixture of talc, or pumice-stone, to enable them to endure the heat better.

Various substances as well as plaster are used for taking models and casts: those which are fluid are used nearly in the same manner as fluid plaster, for similar subjects; and those which are plastic, are used like the plaster employed of the consistence of paste. Sulphur, isinglass, and clay, are often used. Sulphur and isinglass are very proper for medals and small subjects: thus if a medal be surrounded with a rim of paper, plaster may be poured upon it to form a mould: then when this mould is dried and saturated with oil, it may itself be surrounded with a rim, in the same manner as the medal, and melted sulphur, or a strong solution of isinglass in proof spirit, poured upon it. Either sulphur or isinglass will take a very sharp impression, and they may be beautifully coloured

by mixing them with vermilion, or other suitable colours.* The isinglass forms a substance like horn, and has the advantage of not being brittle. It is particularly proper for silver medals, which sulphur would blacken.

When clay is used for moulds or casts, it should be freed from all gravel and rough sand, and well beaten up with finely-washed sand, to enable it to endure drying without shrinking.

To harden and bronze Plaster Figures.

The hardening of plaster figures may be very simply and effectually performed by boiling them for a quarter of an hour in a solution of alum in water.

To bronze plaster figures, they should first be dipped into or brushed over with isinglass size, till they will imbibe no more; then with a painter's brush, every part of the size which has not sunk into the plaster must be removed, to prevent injuring the sharpness of any of the mouldings. When the figure is dry, brush it over with gold size, prepared as before directed, but use no more of this size than will just moisten the surface, and make it shine. Now leave the figure for a couple of days, in a dry place, where it will be free from receiving dust or smoke, and it will be prepared for bronzing. The bronze, which is a fine powder, and may be had at the colour shops, should be dabbed on with a little cotton-wool; and after every part has been touched, the figure may be set aside for another day. It will afterwards be completed, by rubbing off the loose bronze with a soft brush, or a piece of cotton-wool.

The figures thus bronzed will resist the weather. The bronze may be had of all metallic colours; but that which gives the figures the appearance of real bronze, and the preparation of which is given at page 390 of this vol. has the best effect.

To varnish Plaster.

In a pint of water, put a quarter of an ounce avoirdupoise of the finest white soap grated small. Set them over the fire in a glazed earthen vessel, and when the soap is dissolved, add a quarter of an ounce of bleached wax, cut into small pieces, and stir the fluid till the whole is incorporated, when it is fit for use. Suspend the model to be varnished by a thread, and dip it into this preparation; take it out, and after the lapse of a quarter of an hour, dip it again. Let it stand for about a week, and it may then be polished by rubbing it very gently with a piece of soft fine linen, so as not to remove the varnish.

Another mode of varnishing plaster, but which will not stand the weather like the above, is to brush it over with skimmed milk, till it will imbibe no more, which, after it is dry, will by gently rubbing appear like polished marble.

DESCRIPTION OF A FURNACE FOR THE FOUNDERS OF HARD BRASS.

Brass-founders frequently sustain a very considerable loss by the destruction of the crucibles in which they melt their metal. When this happens in the furnace, which is no uncommon case even to new crucibles, the brass, running into the ash-pit, is generally so much dispersed as not to be worth the trouble of recovery, and even when the crucibles stand tolerably well, the expense of them is still an object of moment. To prevent therefore the inconvenience which crucibles occasion, we have the pleasure to state, that the reverberatory furnace described below is perfectly effective. We are indebted for the communication to the liberality of a correspondent, who has experienced its utility during several years' use.

Fig. 1, (plate Miscellanies,) is a vertical section of this furnace, from the front to the back. Fig. 2, is a section across the bed of the furnace at the tap-hole. Fig. 3, is a horizontal section at the height of the fire-place hearth. The same letters refer to the same parts in all the figures.

a, The flue leading into the chimney. *b*, the door, (made of fire lute,) at which the metal is put in. C, the bed for containing the metal. *d*, the entrance downwards into the ash-hole. *e*, the ash-hole, which is to be closed when the furnace is in use. *f*, the fire-place hearth. *g*, an air-hole, to support the combustion of the fuel. *h*, the entrance at which the fuel is put in; it may be closed sufficiently by the coals themselves. *i*, the brick-arch or crown of the furnace; this arch, as well as the sides of the furnace, should be built of Stourbridge bricks. O, the tap-hole, at which the metal is let out, when completely fused. The size of the furnace represented in the plate, as designated by the scale, will contain upwards of three quarters of a hundred-weight of metal.

STAINING WOOD.

Stains do not lie, like paints, upon the surface of wood, but sink more or less into its substance. Hence the wood which has been stained, exhibits its natural grain and hardness: and it must be remembered, that if the wood be not white, the colour taken will be a compound of that of the wood and the stain. The dyeing woods employed must be understood to be in small chips, or raspings.

When the wood is mentioned to be brushed several times over with any fluid, it should be dried previous to each repetition of the operation. The woods which have been stained, are afterwards rubbed up with rushes, then with a cloth, dipped in a solution of bees' wax in spirits of turpentine; and afterwards rubbed with a woollen cloth alone. When the stain is intended to be very deep, the pieces should be boiled in the staining liquor, and not merely brushed over.

To stain Wood Red.

Take two ounces of Brazil wood, and two ounces of potash; mix them with a quart of water; and let the composition stand in a warm place for several days, stirring it occasionally. With this liquor, made boiling hot, brush over the wood, till the desired depth of colour is obtained. Then with another brush, brush over the wood, while yet wet, with a solution of alum, in the proportion of two ounces of alum to a quart of water.

For a pink or rose red, use double the quantity of potashes.

To stain Wood Yellow.

Infuse an ounce of turmeric in a pint of spirits of wine, and let the mixture stand for several days closely covered, shaking it occasionally. Brush over the wood with this infusion. A reddish yellow may be given to the colour by the addition of a little gum-tragacanth.

Diluted nitric acid will stain wood yellow.

To stain Wood Green.

Dissolve verdigris in vinegar, or crystals of verdegris in water, and brush over the wood with the hot solution.

To stain Wood Blue.

Dissolve copper in diluted nitric acid, and brush it while hot several times over the wood; then make a solution of pearl-ashes, in the proportion of two ounces to a pint of water, and brush over the stain made with the solution of copper, till the colour be perfectly blue.

The green stain made as above with verdegris, may be changed to a blue by the solution of pearl-ashes.

The sulphate of indigo, which may be had ready prepared of the dyers, will, when diluted with water, make a blue stain.

To stain Wood Black.

Brush the wood several times with a hot decoction of logwood, then several times with common ink.

To make a very fine black, brush over the wood with a solution of copper in nitric acid as for blue, and afterwards with logwood, till all the greenness of the copper solution is gone.

To stain Wood Purple.

Take one ounce of logwood, and two drachms of Brazil wood; boil them together in a quart of water over a moderate fire. When one half of the fluid is evaporated, strain the decoction, and brush it several times over the wood. After the wood is dry, brush it over with a solution of a drachm of pearl-ashes in a pint of water.

To stain Wood a Mahogany Colour.

Two ounces of madder, and one ounce of fustic, boiled in a quart of water, make a light mahogany stain: but a dark stain may be obtained by using half an ounce of logwood, instead of the madder, and brushing the stained wood over with a weak solution of potash.

CONSTRUCTION OF A TEMPORARY SCAFFOLD,

FOR REPAIRING THE INTERIOR OF DOMES.

This scaffold is contrived to move round on an upright pole, in the centre of the dome, and on two wheels running on the floor, so that it can be turned to all parts of the interior of the dome.

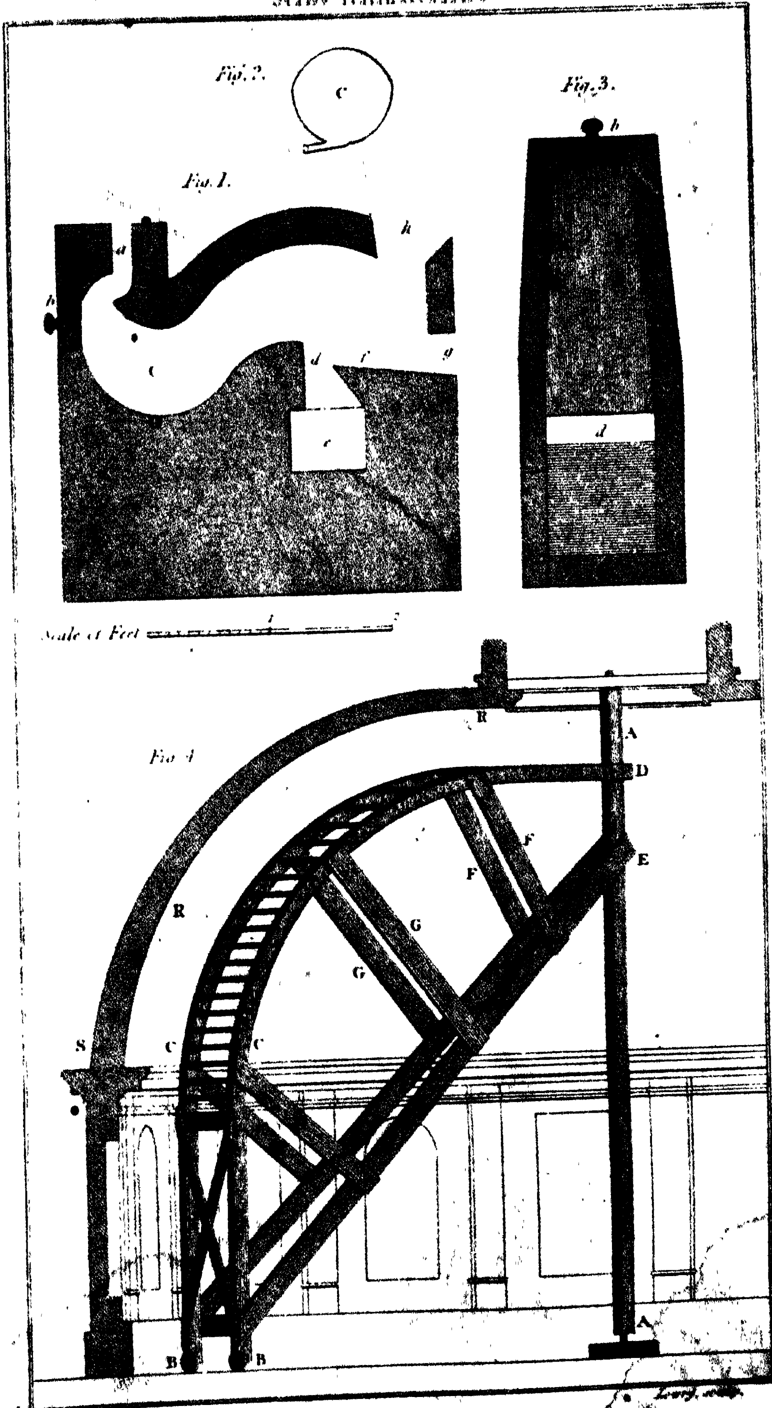
Fig. 4, (plate Miscellanies) represents an oblique elevation of the scaffold, as erected in the dome RR, of the building S. The chief support is a straight scaffold pole, AA, which turns on a pivot at the top, supported by a piece of wood fixed across the top of the dome in the centre; and is supported at the bottom on another pivot, resting in a step of wood fixed on the floor. To this pole, a light braced frame is fixed, and traverses round on two rollers BB; these are situated at the bottom of the two upright legs KK, which are nearly as high as the walls of the building. The tops of these support the ends of two curved planks CC, the upper ends of which are bolted on each side of the centre-pole at D. Between these planks, a number of boards or planks are placed horizontally, so as to form a scaffold, on which the workmen stand to work at the interior of the dome, at any height they find convenient. The width of these steps gradually diminish from the space between the two uprights BB, to a very small width at the pole near D.

The whole machine is braced by the two diagonal stays II, extending from the uprights at the bottom BB, and secured to the upper part of the pole at E.

The curved planks CC are also strengthened and supported by the short braces FF, GG, and HH, which extend from the stays II to the curves CC; these form a strong and secure scaffold, which may be easily moved round to any part of the internal dome at pleasure. To strengthen the frame sideways, diagonal braces are applied between the two uprights KK.

This scaffold is the invention of G. Hughes, a respectable painter and plasterer of Manchester. It was used for repairing and beautifying the Exchange in that town, and the ex pense of its erection did not exceed £4; the estimate for a scaffold on the common plan, for the like purpose, would have been £40 or £50. The inventor was rewarded by the Society for the Encouragement of Arts, &c. with a silver medal.

In cases where the elevation of the dome is very considerable, a great degree of security might be obtained, by the addition of a railing to the scaffold.


Fig. 2.
c
Fig. 3.
h
d
Fig. 1.
h
a
h
c
d
f
g
e
Scale of Feet
1
2
Fig. 4
R
A
D
E
F
F
R
G
G
S
C
C
A
B
B

Method of breaking up Logs of Wood.

The large roots of trees, and other logs of wood, are frequently suffered to accumulate in farm-yards and other places, because, though they would supply a large quantity of fire-wood, the trouble of working them up with the saw or the axe, would not be compensated by their value. Knight, of Fosterlane, London, therefore introduced a method, which has been successfully practised, of blasting such logs of wood with gunpowder. He bores with an auger, the wood intended to be broken up, then puts a charge of powder into the hole, which he closes by screwing into it a screw of a proper size. The screw, having been prepared for the purpose, has a hole made through its axis; this hole is filled by a wire when the screw is put into the hole, but the wire is drawn out afterwards, and a match, made of a piece of twine, dipped in a solution of nitre, is put in its place. This match being set fire to, burns slowly, and allows the operator time to retire to a sufficient distance before the explosion. The screw is not injured by the operation.

The blasting of timber, may, however, be considerably simplified; it will be sufficient, merely to fill the hole with common sand, after the charge of gunpowder has been introduced. The communication may be maintained by any slight tube, as a straw, or a reed. The sand requires no wedging with stones above, but merely a slight pressure to make it lie close. It is a singular fact, that so loose a substance should not be blown out of the hole without the least injury to the wood, but it is certain that the force with which it retains its place in such a situation, is sufficient not only to break up wood, but the hardest rocks.

To take Impressions of Plants.

Take the green plant, and spread it out upon paper, in such a manner as to display the proper character of the plant, in the best manner that a plain surface will admit: then place it between the leaves of a book, and leave it under a weight for some days. When it has become stiff and dry, take it out, and with a camel-hair pencil smear the whole of it with Indian ink; turn the painted side down upon a clean piece of paper which has been sponged with water at the back. Place a few leaves of paper upon it, and again leave it under a weight, for about half an hour.

In this manner impressions of plants may be taken, which will have a soft and beautiful effect, and will characterise the plant with a degree of force not often observed in engravings. Care should be taken that the ink be not used so plentifully as to make the impression too black, or to press out beyond the limits of the specimen. Any slight deficiencies which appear, may be supplied with a pencil.

It has been usually recommended to use a printer's ball and ink for taking impresssions; but the effect in this way is not superior, the difficulty of managing the process is increased, and the conveniences required are not so easily attainable. Those balls which persons may make for themselves of white leather, as substitutes for printer's balls, will not answer, as they will lay the ink on in a daubing disagreeable manner, very differently to those balls which the printers have in con stant use, and which are made of raw skins.

Method of cutting Glass by Heat.

Take a piece of dense charcoal, made from box or some other hard wood, and point it like a pencil. Scratch the glass, at the place where the fracture is to begin, with any instrument of hard steel, such as the corner of a file. Light the point of the charcoal, and applying it to the scratch, proceed with pressing it upon the glass in the direction of the intended fracture. The glass will crack in the path of the burning point, and the crack may be either in a right line, or zigzag, or curved, at pleasure. As fast as the point of the charcoal becomes covered with ashes, it should be blown upon with the breath to keep it red hot, or it will not heat the glass sufficiently to produce the desired effect. The scratch made on the glass at the commencement, need scarcely be more than a point.

Method of filling up Engraving on Silver with a durable black Enamel, as practised in Russia, Persia, and India.

Take half an ounce of silver, 2½ ounces of copper, 3½ ounces of lead, and 2½ ounces of muriate of ammonia; melt the metals together, and pour the compound into a crucible which has been before filled with pulverized sulphur, made into a paste by means of water: the crucible is then immediately covered, that the sulphur may not take fire, and the mix ture is calcined over a smelting fire, until the superfluous sul-

phur is burnt away. The compound is then coarsely pounded, and with a solution of muriate of ammonia formed into a paste, which is rubbed into the engraving on silver plate. The silver is then wiped clean, and suffered to become so hot under the muffle, that the substance rubbed into the strokes of the en graving melts and adheres to the metal. The silver is after wards wetted with the solution of muriate of ammonia, and again placed under the muffle till it becomes red hot. After this, the engraved surface may be smoothed and polished, without any danger of the black substance, which is an artificial kind of silver ore, either dropping out or decaying.

Method of making Sealing Wax.

Take any quantity of shell-lac in powder; add to it half its weight of rosin, and half its weight of vermilion. Melt these ingredients over a gentle fire, and when they are thoroughly incorporated, work the composition into sticks, rolls, or any other form desired.

This composition makes a fine, hard, red sealing wax: any other colour may be obtained by using a pigment of the co lour desired, instead of vermilion.

Red lead is used instead of vermilion for common red wax, and the quality of the composition is further debased by re versing the proportions of rosin and shell-lac.

The whitest rosin should be used for all bright colours. The wax will be more tenacious, if turpentine, boiled with a little water till it is hard, is used instead of rosin. The lowest heat at which the ingredients can be melted, should also not be exceeded.

The sealing wax may be softened by adding white wax to it; it is formed into sticks by rolling it upon a stone while it is yet soft; and is polished merely by melting its surface ove a fire, and letting it cool without being touched.

Method of taking Impressions on Paper, from Designs made on Stone.

Take a fine-grained stone which will imbibe water, let the surface of it be made smooth, flat, and free from scratches, but not polished; draw or write on it with ink formed by dissolving lac in a ley of pure soda, and intimately incorporated

with some lamp-black, that the strokes made with it may be distinctly seen. When the design is completed, leave it to dry and harden for three or four days, and it will then be ready for using in the following manner. Immerse the stone in water for a couple of hours; on taking it out, remove the water lying on its surface with a fine piece of linen or silk; then dab the design with a printing-ball, in the same manner that printers dab the wood cuts they are printing. The printing ink will adhere to the design, because the resinous composition with which it was made, not imbibing water, was dried by the linen or silk rag; but the bare surface of the stone repels the ink, because the water has entered its texture. The impression may be taken on damp paper by means of a printing press, or by the rolling press of copperplate printers. Several hundred copies may be taken from the same design in this simple manner. When the printing press is employed, the thickness of the slab should be equal to the height of printing types, or about nine-tenths of an inch, and must be very flat on both sides, or the pressure will be apt to break it; the edge of the upper surface should be rounded, that it may not catch the ink from the printing ball.

The stone employed should be of a light colour, that the design may be easily seen upon it; and of a fine grain, that the pen may move easily over it, and make perfect strokes; yet it must be easily penetrable by water; the stone which has hitherto been found the best, is of the calcareous class, nearly white: the most porous kinds of light blue slate would probably answer.

The art of printing from stone, above described, has recently become particularly interesting, by the prospect there appears to be, that it may in part supersede the use of engraving upon copper and wood. The effect of the impressions much resembles that of chalk engraving, but designs exhibiting considerable precision have been executed in this style, and it will probably yet receive great improvement; its greatest defect is uniformity of tone, but it affords artists the singular advantage of having their original sketches multiplied by printing, without either the expense of engraving them, or the loss of spirit to which they are liable in the copying and recopying which engraving requires.

Ppocess for removing Spots of Grease from Books and Prints.

After having gently warmed the paper stained with grease,

wax, oil, or any fat body whatever, take out as much as possible by means of blotting paper, having first scraped off with a blunt knife what was not sunk in, and gently warmed the stained part. Then dip a small brush in well rectified spirits of turpentine, heated almost to ebullition, (for when cold it acts very weakly,) and draw it gently over both sides of the paper, which must be carefully kept warm. This operation must be repeated as many times as the quantity of the fat body imbibed by the paper, or the thickness of the paper, may render necessary.

When the grease is entirely removed, recourse may be had to the following method to restore the paper to its former whiteness, which is not completely restored by the first process. Dip another brush in alcohol, and draw it, in like manner, over the place which was stained, and particularly round the edges, to remove the border that would still present a stain.

By employing these means with proper caution, the spot will totally disappear, and the paper assume its original whiteness; if the process has been employed upon a part written on with common ink, it will experience no alteration.

Method of discovering whether Wine contains any Metal prejudicial to Health.

Mix equal parts of oyster-shells and crude sulphur in fine powder, and put the mixture into a crucible. Heat it in a wind furnace, and increase the heat suddenly, so as to bring the crucible to a white heat for the space of fifteen minutes. Pulverize the mass when it is cool, and preserve it in a bottle closely stopped.

To prepare the proving liquor, put one hundred and twenty grains of this powder, and one hundred and twenty grains of cream of tartar, into a strong bottle; fill the bottle with common water, which boil for an hour, and then let it cool; close the bottle immediately and shake it for some time. After it has remained at rest to settle, decant the pure liquor, and pour it into small phials capable of holding about an ounce each, first dropping into each of them about twenty drops of muriatic acid. They must be stopped very closely with a piece of wax, in which there is a small mixture of turpentine.

One part of this liquor, mixed with three parts of suspected wine, will discover, by a very sensible black precipitate, the least traces of lead, or copper; it precipitates arsenic of an orange colour, but produces no effect upon iron, if the wine

contain any of that metal. When the precipitate has fallen down, it may still be discovered whether the wine contains iron, by saturating the decanted liquor with cream of tartar, (super-tartrate of potass) by which the liquor will immediately become black. Iron, which is not noxious, but rather salutary, frequently gets into wines by accident.

Pure wines remain clear and bright, after this proving liquor has been added to them.

Method of preserving Birds.

Open the bird at the vent, extract the entrails, lungs, craw, &c. wash out the cavity with a solution of one ounce of muriate of ammonia dissolved in a quart of water, in which afterwards two ounces of corrosive sublimate of mercury must be put; or four ounces of arsenic may be boiled in two quarts of water, till all, or the greatest part, be dissolved. Suspend the bird by the bill to drain; then strew the inside with a powder, made of four parts of tobacco sand, four parts of pounded pepper, one part of burnt alum, and one part of corrosive sublimate or arsenic; then fill the body with oakum or tow, steeped in the above liquor; take out the tongue, and scoop out the brain through the mouth; fill these cavities also with steeped tow. The attitude is given by sharp-pointed wires, one end being thrust through the legs, breast, and neck, also through the wings and body across. Dry the bird gently in an oven, taking care that the heat is not too powerful, which may be known by a feather or a hair, put for trial's sake into it. If the heat be proper, the feather will neither crisp, curl, nor bend. If at any time the bird gets moist, have recourse to the oven, or a gentle fire, which will recover its lost elasticity, and preserve it any length of time. Eyes may be procured at any glass manufactory, or they may be bought at any of the dealers in birds and curiosities in London; or the eye sockets may be filled up with putty, and painted according to nature.

The recipe of the late Sir Ashton Lever, for preserving birds, was a mixture of one pound of salt, four ounces of alum, and two ounces of black pepper; in every other matter as just directed, except the use of the liquid, and drying the subject by the oven. He suspended the birds by the feet, in a fine, cool, airy place, for the salt to impregnate the body; afterwards by a thread run through the under mandible, till it appeared to be perfectly sweet; then hung it in the sun or near the fire.

The preserver of birds, at the late Leverian Museum, adopted a very excellent mode of supplying his subjects with eyes; it consists in using a hemisphere of polished glass, on the plane side of which is painted a correct representation of the iris, pupil, &c. of the eye. The eyes thus formed, have a lively natural effect.

To render Boots and Shoes waterproof.

Take one pint of drying oil, two ounces of yellow wax, two ounces of spirits of turpentine, and half an ounce of Burgundy pitch; melt them over a slow fire, and thoroughly incorporate them by stirring. Lay this mixture on new shoes and boots, either in the sun or at some distance from the fire, with a sponge or brush; and repeat the operation as often as they become dry, until they are fully saturated. The shoes and boots thus prepared, ought not to be worn until the leather has become perfectly dry and elastic. They will then be found impervious to moisture, and their durability will be increased.

Fluid for Steeping Seeds, to prevent the Depredations of Vermin.

H. Brown, of Derby, observes to the Society for the Encouragement of Arts, &c. that when he steeped seeds for three or four hours, or for a sufficient length of time to penetrate the husk, in a strong solution of liver of sulphur, he never lost a seed by vermin during a three years' trial.

Preservation of Crops by Elder.

If branches of elder be brushed occasionally over plants, such as cabbages, cauliflowers, turnips, or any other productions of the garden, the operation is found to have a remarkable effect in preserving the plants from the attacks of insects, and also preserving fruit-trees from being blighted.

Method of obtaining very strong Lemon Juice.

Express the juice of ripe lemons in the usual manner, and strain it through a piece of linen. In half an hour strain it again, to free it from the small portion of slimy matter which will have settled at the bottom of the vessel. Then add to the juice some of the strongest spirits of wine, and preserve the liquor for some days in a well corked bottle. Filter the liquor through paper; but if too thick to pass through the filter, dilute it again with spirits of wine. After the last filtration, the acid of lemons may be freed from the spirits of wine by the evaporation of the latter. The acid, after being thus freed from the spirits of wine and moisture combined with it, assumes a yellowish colour, and becomes so strong, that by its taste it might be considered a mineral acid.

New Mode of preparing Vinegar.

Take a cask made of oak, of a size proportioned to the quantity of vinegar required; this cask must have a bung about an inch and a half from the bottom, for the purpose of drawing off the liquor, but it must be set on one end to perform the operation. Rain or river water only can be used for this preparation; a quantity of either must be put into the cask equal to the quantity of vinegar required.

To 13 quarts of water, add half a pint of brandy, 4 ounces of tartrate of potass, 12 ounces of sugar, and 6 ounces of yeast

Reduce the tartrate and sugar to powder, dissolve them in warm rain water, adding the yeast, so as to form a thick solution, which, being mixed with the brandy, must be poured into the cask, and the latter must be placed in a warm situation for about six weeks.

Before the cask is bunged up, the water and other ingredients contained in it should be shaken together, to mix them as much as possible. Half an hour is sufficient to render the mixture complete. This vinegar, when drawn off into bottles and well corked, will keep a long time, and is not inferior to any vinegar hitherto known.

A NEW, EASY, AND CHEAP METHOD OF IMPREGNATING WATER WITH CARBONIC ACID GAS.

Dr. Fierlinger has proposed the following very simple mode of impregnating water with carbonic acid gas. He fills common round bottles with water, inverts them carefully under water, in order to prevent any air from entering, and charges them with carbonic acid gas, in the usual manner of transferring gasses from one vessel to another, (see p. 308 of this vol.) He then corks the bottles, thus filled, under water with a ventilated stopper, immerses them under water in a cylindrical vessel, two feet high, and of a proportionate width to the diameter of the bottle, in order to apply, according to hydrostatic laws, a great pressure with a small quantity of water. The bottles thus filled with the gas, and entirely immersed, imbibe water by means of the affinity the carbonic acid has for it, in such a manner that they are nearly filled; and water is thereby obtained, impregnated with an equal volume of gas, the water having lodged itself in the interstices of the gas.

This method has, besides its convenience and cheapness, still other advantages; the degree of impregnation may be regulated by the height of the column of water under which the bottle is immersed, and the water is prepared in those vessels out of which it is to be drank, and this prevents that escape of gas which always takes place in pouring from one vessel to another, especially if the water be strongly impregnated.

The above-mentioned ventilated stoppers, are corks fitted exactly to the bottles, perforated lengthways, by holes drilled through them, the uppermost orifices of which are covered

with a small plate of pewter, fastened to the cork by means of a string passed through a hole in the centre, and drawn through the cork. If this small plate be furnished with a little cavity, in which iron filings are put, the wates becomes chalybeate.

On the Application of Platina to Porcelain.

For this purpose, platina is dissolved, in nitro-muriatic acid, and precipitated by a solution of muriate of ammonia. The red crystalline precipitate formed is to be dried, reduced to a fine powder, and made slightly red hot in a glass retort. The muriate of ammonia, which had precipitated in combination with the platina, sublimes; and the metal remains at the bottom of the retort in the form of a light gray powder. This powder being mixed with a small proportion of flux, as is done with gold, and ground with oil of spike, is to be applied to the porcelain, put into the furnace, and afterwards burnished.

Platina, applied on porcelain in this manner, is of a silver white, slightly tending to the gray of steel. By alloying this metal in different proportions with gold, different shades of this colour are obtained. Platina admits a considerable quantity of gold, before its colour undergoes any perceptible change to yellow. For example, if one part of platina be alloyed with four parts of gold, the presence of the latter cannot be perceived, and the colour scarcely differs from that of pure platina. The colour of the gold does not predominate, unless it be in the proportion of eight to one. The alloys of platina with silver give only a dull metal.

Besides this method of applying platina to porcelain, it may be laid on in the state of solution. In this way, its colour, lustre, and appearance, are very different. If the nitro-muriatic solution of platina be evaporated to a consistence suitable for painting with, and several times laid on the porcelain, the metal penetrates into its substance, which, after it comes out of the furnace, exhibits a metallic mirror of the colour and brilliancy of polished steel.

To obtain Nitric Ether without Heat.

Into a tubulated retort is introduced one ounce of sugar, and two ounces of pure alcohol are poured upon it. To the retort is adapted a capacious receiver, enveloped with a cloth dipped in cold water, and the joinings are secured with a single slip of paper. Upon this matter, three ounces of highly concentrated and smoking nitric acid are poured through the tube of the retort. An effervescence instantly takes place, the mass becomes heated, the sugar is dissolved, ebullition ensues, and the alcohol is etherized, and passes from the retort into the receiver. Thus, in a little time, may be collected in the receiver all the alcohol, converted into excellent ether, of a light orange colour, and a very agreeable smell; which does not turn vegetable blue dyes red, and acts in every respect like the best ether from nitric acid.

After the fermentation of the ether, a small quantity of nitrous gas is disengaged in this operation; it is discovered by a red vapour, which spreads through the apparatus. As soon as it is observed, the receiver should be changed. In the retort is left some sugar, which may easily be converted into oxalic acid, by treating it with a fresh quantity of nitric acid.

Method of preparing perfectly pure Caustic Ley

Boil equal parts of purified salt of tartar, (tartrate of potash, or vegetable alkali prepared from tartar,) and Carrara marble, burnt to lime, with a sufficient quantity of water, in a polished iron kettle; strain the ley through clean linen, and though yet turbid, reduce it by boiling, till it contain about one half of its weight of caustic alkali; after which pass it once more through a linen cloth, and set it by in a glass bottle. After some days, when the ley has become clear of itself, by standing, carefully pour it off from the sediment into another bottle. To be convinced of its purity, saturate part of it with muriatic or nitric acid, evaporate it to dryness, and re-dissolve it in water. If it be pure, no turbidness will take place in the solution. The quantity of caustic alkali, which this ley contains, may be ascertained by evaporating a certain weighed por-

tion of the ley to dryness, in an evaporating dish of a known weight. In the preparation of this caustic ley care should be taken that the alkali be not entirely deprived of carbonic acid, because in that case we can, with greater certainty depend on the total absence of dissolved calcareous earth. By employing burnt marble, or, in its stead, burnt oyster-shells, the usual contamination of the caustic ley with aluminous earth may be avoided; because lime, prepared from the common species of limestone, is seldom free from argil.

Charcoal Crucibles.

In the analysis of fossils, Klaproth found charcoal crucibles of great utility: he used them in the following manner: taking a sufficiently large fragment of well-burned charcoal, he made in it a cavity of a size answering to that of the fossil. This cavity, after the fossil was put into it, was closed with a charcoal stopper; after which the charcoal crucible was fitted into a crucible of baked clay, and this last was well joined to its cover by luting.

In order to make comparative experiments, he placed an other quantity of each fossil immediately in a crucible made of clay unmixed with iron. After the cover had been luted on, it was exposed to the same heat.

Method of preparing a cheap Substitute for Oil-paint.

It often happens that people do not choose, or cannot employ oil-painting in the country, either because it does not dry soon enough, and has a disagreeable smell, or because it is too costly. Ludicke employed with the greatest success the following composition for painting ceilings, gates, doors, and even furniture.

Take fresh curds, and bruise the lumps on a grinding-stone, or in an earthen pan or mortar, with a spatula. After this operation, put them in a pot with an equal quantity of lime, well quenched, and become thick enough to be kneaded: stir

this mixture well without adding water, and a whitish semi-fluid mass will be obtained, which may be applied with great facility like paint, and which dries very speedily. It must be employed the day it is prepared, as it will become too thick the day following. Ochre, Armenian bole, and all colours which hold with lime, may be mixed with it, according to the colour desired; but care must be taken that the addition of colour made to the first mixture of curds and lime, contain very little water, or it will diminish the durability of the painting.

When two coats of this paint have been laid on, it may be polished with a piece of woollen cloth, or other proper substance, and it will become as bright as varnish. This kind of painting, besides its cheapness, possesses the advantage of admitting two coats to be laid on and polished in one day, as it dries speedily, and has no smell.

Preparation of the Substance called Asses Skin, used for Memorandum Books, &c.

Take either vellum, parchment, very fine cloth, or paper, and stretch it in a frame as tight as possible; then take twelve pounds of white lead, and grind it very fine; add to it one-third part of the best plaster of Paris, and one-fourth part of the best stone lime; mix them well together, and levigate them thoroughly with water. Then take a new glazed vessel, and dissolve six or seven pounds of the best double size over a fire, and mix the above ingredients with it till it is of such a consistence that it may be laid on with a brush. Lay three or four layers of this composition on the skin or cloth, as smooth as possible, observing that the skin is dry each time, before a second layer is laid on. Then take the best nut or linseed oil, and to every pound of this oil add four ounces of the best white varnish, and mix them well together. Lay on three or four layers of oil, thus prepared, each time exposing the surface to the air till it is thoroughly dry.

The above composition is for the white sort of artificial asses' skin; for a brown or yellow, add to every pound of the oil and white varnish, three or four ounces of the best stone ochre, or orpiment, or Dutch pink, and three or four ounces of litharge. These must be well ground with very old linseed oil, and laid on, as smooth as possible, ten or twelve times

exposing the surface each time to the air, to be thoroughly dry before a second coat is given; and it must be placed where no dust or dirt can fall upon it. The colour may in the same manner be varied at pleasure; as, for instance, to a red by vermilion, to a blue by Prussian blue; and to a black by pounding slate, grinding it very fine, and mixing it with as much ivory black as will turn it to a fine black colour.

When the skin, paper, or cloth, thus prepared, is thoroughly dry, it may be written on with a black or red lead pencil.

To make Artificial Grindstones.

In India, they form grindstones in the following manner: take of river-sand three parts, of washed seed-lac one part; mix them over the fire in a pot, and form the mass into the shape of a grindstone, having a square hole in the centre; fix it on an axis with the liquefied lac, heat the stone moderately, and by turning the axis, it may easily be formed into an exact orbicular shape.

Polishing grindstones are made only of such sand as will pass easily through fine muslin, in the proportion of two parts of sand to one of lac.

To preserve Wood in damp situations.

Two coats of the following preparation are to be applied, after which the wood is subject to no deterioration whatever from humidity. 12lbs of rosin are to be beaten in a mortar; to which three pounds of sulphur, and 12 pints of whale oil, are to be added. This mixture is to be melted over the fire, and stirred during the operation. Ochre, reduced to an impalpable powder by triturating it with oil, may then be combined in the proportion necessary to give either a lighter or a darker colour to the material. The first coat should be put on lightly, having been previously heated; the second may be applied in two or three days, and a third after an equal interval, if, from the peculiar dampness of the situation, it should be judged expedient.

Patent Size.

In the year 1800, a patent was taken out by Thomas Foden, of Coventry, for making size agreeably to the following specification:

"I take a quantity of calcined gypsum, or any other calcareous or argillaceous earth, and reduce it to a fine powder. I then mix the same with alum, sugar, and the gluten or farina of potatoes, or any other vegetable gluten. I then take any given portion of this powder, and mix it well with cold water, into a soft paste. Then I take water in a state of ebullition, and pour it on the mixture, stirring it round till it is sufficiently united and gelatinous. I then, by the addition of the vegetable or mineral alkali, treacle, or glue, temper it to all weathers. This size will be found superior to any made with flour, glue, &c. in the sizing and dressing all kinds of yarn, as the mucus from flour requires to be corrected by a strong alkali."

Method of preparing Britannic Elastic Gum.

Take linseed-oil, or nut-oil, one gallon; bees-wax, yellow or bleached, one pound; glue or size, six pounds; verdigris, a quarter of a pound; litharge, a quarter of a pound; spring or rain water, two quarts: to be put into an iron kettle, and melted till the whole becomes a uniform composition.

For this preparation a patent was taken out. The inventor states it to be very serviceable in the several branches of portrait and house painting, by making the colours durable and free from peeling; also of great utility in gilding, painting, pencilling, and straining of silks, calicoes, &c. and in dressing of silk, linen, and cotton, in the loom, instead of gum or paste, so as to strengthen the threads of the finest cotton; and also excellent for beautifying and fixing the colours upon paper, equal to that done in India; and of the greatest use for rendering the clay, or composition used in modelling, supple, and preventing the same from drying too fast; and for causing a transparency of colours fit for china and earthenware, so as to stand baking or burning.

Method of restoring Writings effaced by oxygenated Muriatic Acid.

This process was published in the Moniteur, by order of the French government. It was invented by Guietaud, apothecary of the Grand Hospital of Humanity.

The sulphuret of ammonia and the prussiate of potass are the two substances which he prefers. The disagreeable smell of the sulphuret of ammonia will no doubt prevent many persons from employing it: it has, however, this advantage, that it does not stain the paper, and that it makes the writing re-appear when simply exposed to its vapour in a close vessel, or under a bell-glass. But to produce this effect more speedily, it will be best to pour a few drops of it into water, and to dip the paper in it: the effaced writing soon re-appears of a dark brown colour, and exceedingly legible.

The prussiate of potass gives a blue colour to the writing, whether that effaced or that which has been substituted for it, which is sufficient to detect fraud of this kind: it gives to paper, at the same time, a slight tint of blue. To employ it, put into a basin, or any other deep vessel, and of a suitable size, as much water as may be sufficient for immersing the leaves of paper to be subjected to examination. Then add about half a thimble-full of the prussiate; and, when it has been well mixed with the water, immerse in the liquid a leaf of paper. When it has imbibed the liquid well, a few drops of sulphuric, or any other acid, poured into the mixture in such a manner as to render it slightly acid, will be sufficient to make the writing re-appear. It is well known, that the same substance possesses the property of reviving old writing, if employed in the like manner

Of the Oil obtained from the oliferous China Radish.

The oliferous China radish, (the *raphanush Chinensis annuus oliferus* of Linnæus,) has of late years been cultivated in Piedmont and the Milanese. From 3½ ounces of seed, a farmer, named Grandi, obtained a produce of 583 pounds, which

yielded 200 pounds weight of oil. The Chinese extract from the seed half its weight of oil. This oil is employed by the Italians for culinary use; it burns without emitting smoke, and gives quite as clear a light as common oil. In the Milanese, the plant is sown between the beginning of March and the middle of April. The land is ploughed in autumn, and again before the seed is sown, but is not manured. It is then rolled, so that the seed is covered about half an inch. The plants are thinned, so as to leave a distance between them of not less than 2½ inches, and not more than five. If broken down by hail or other accidents, they push out new shoots, which yield seed equally good and abundant with the parent stem.

CHEMICAL EXPERIMENTS.

The Chemical Weather-Glass

A bottle or vessel of glass, about ten inches long, and three quarters of an inch in diameter, filled with a peculiar mixture, has been recently sold to answer the purpose of the barometer, by the changes which it exhibits according to the state of the weather. The following is stated by Wiegleb to be the mode of composing this fluid. Two drachms of camphor, half a drachm of purified nitre, and half a drachm of muriate of ammonia, are to be pulverized, and dissolved in two ounces of proof spirits. This composition is to be put into a glass vessel, as above described, the mouth of which is to be covered with paper, or a piece of bladder perforated with a needle.

The changes which appear in this composition are stated to be of the following nature. If the weather promise to be *fine*, the solid matter of the composition will settle at the bottom

of the tube while the liquid is pellucid; but previous to a change for rain, the compound will gradually rise, the fluid will continue transparent, and small stars will be observed moving or floating about within the vessel.

Twenty-four hours before a storm, or very high wind, the substance will be partly on the surface of the liquid, apparently in the form of a leaf: the fluid in such case will be very turbid, and in a state resembling fermentation.

During the winter, small stars being in motion, the composition is remarkably white, and somewhat higher than usual, particularly when white frosts or snow prevail. On the contrary, in the summer, if the weather be hot and serene, the substance subsides closely to the bottom of the glass tube.

Lastly, it may be ascertained from what point of the compass the wind blows, by observing that the solid particles adhere more closely to the bottom, on the side opposite to that where the tempest arises.

The Phosphoric Fire or Match Bottle.

Take a piece of phosphorus, about the size of a pea, put it into a very small phial, and fill up the bottle with quicklime in powder. Set the bottle in the midst of some sand contained in an iron vessel of any kind, and place the iron vessel over a gentle fire. The bottle should be loosely stopped with a cork, and while it is gradually warming, its contents should be occasionally stirred; but two great an access of air must be avoided, to prevent their catching fire. When the whole of the lime has become of a reddish yellow colour, the phosphorus may be considered as having combined with it, and the bottle may be taken from the fire. It should be kept well corked, and opened as seldom and for as short a time as possible. When a brimstone match is introduced into this composition, and stirred about a little, it will instantly be lighted.

Another mode of forming a fire-bottle, consists in mixing one part of sulphur with eight of phosphorus. A match introduced into this composition, and then rubbed upon a piece of cork or any similar substance, is immediately lighted by the friction.

To gild a Ribbon chemically.

Take a silk ribbon, wet it thoroughly with phosphorized ether, and then dip it into a solution of muriate of gold, which will gild it in a manner that will bear washing.

The phosphorized ether is prepared by letting ether stand over phosphorus for some weeks.

The Artificial Volcanoes.

Take nitre and cream of tartar, of each one ounce; let them be reduced to a fine dry powder, and well mixed; add to them a little powdered charcoal, and raise the whole into a heap, in the form of a pyramid; set fire to the vertex, and the clouds of smoke, the flashes of light, the hissing noise, and the torrents of red-hot lava which will roll down the sides, entitle it to the appellation of the artificial volcano. The residuum is vegetable alkali, which may be kept in bottles for use.

Mix equal quantities of flowers of sulphur and iron filings or turnings, form them into a paste with water, and bury the mass in the earth at the depth of about a foot. In about twelve hours afterwards, if the weather be warm, the earth will swell up and burst, flames will issue forth, and a yellow and blackish dust will be scattered about. There should be a considerable mass of the composition; for example, fifty pounds.

Beautiful Appearance from the sudden Combustion of Oil.

Pour half a spoonful of olive oil into a small crucible, obscurely red, or at that degree of heat, which will have been discovered by some previous experiments. A thick cloud of white smoke will immediately rise, which takes fire at its

summit, that is to say, four or five feet distant from the crucible. If, on the contrary, the combustion of the cloud arises from the crucible, it is occasioned by the heat being too great. In that case it will be proper to wait a few minutes, when the phenomenon will appear in all its magnificence.

Gas Light.

Fill the bowl of a tobacco-pipe with pulverized coal, and lute the mouth of it with a mixture of clay and sand. Put it in the fire, and when it becomes red hot, apply a lighted candle to the end of the tube; the gas which issues from it will take fire, and will continue to burn with a bright flame, till the coal in the pipe-head is burnt to a cinder. The gas thus obtained is the carburetted hydrogen which is employed under the name of gas-lights. The residuum in the bowl of the pipe is coke.

Detonating Mixture.

Mix sulphuret of antimony with half its weight of hyper-oxymuriate of potass, place a few grains of the mixture upon an anvil, and strike it sharply with a hammer; it will explode with a loud report, and an intense light.

Fulminating Powder.

Mix together in a mortar, three parts of nitre, two of potash, and one of sulphur. Put a little of this powder upon a shovel, and heat it slowly by placing the shovel on the fire. At the instant of its beginning to melt, it explodes with a violent report. This compound is not dangerous, like the metallic fulminating powders; but as much of it as will lie upon a sixpence, is sufficient to use at a time.

COMBUSTION UNDER WATER.

Put a small quantity of hyper-oxymuriate of potass and a bit of posphorus into a wine glass, and pour cold water upon them. Take a glass tube, and dip one end of it into sulphuric acid, press with a finger upon the upper orifice, to retain the acid which has entered the tube, and convey that end to the bottom of the wine glass, and then taking the finger from the top of the tube, the acid will immediately cause the combustion of the ingredients under water.

HEAT PRODUCED BY THE MIXTURE OF TWO COLD FLUIDS.

To any quantity of sulphuric acid, in a glass bottle, add one-fourth of its measure of water, and shake up the mixture once or twice. The part of the bottle occupied by the fluid will immediately become too hot to be held in the hand. Unless the bottle be strong, it is advisable not to make suddenly more than half a pint of the mixture, to avoid any accident.

TRANSCOLORATIONS.

To a weak solution of galls, add a few drops of weak solution of sulphate of iron: the fluids, separately, are transparent, and devoid of colour, or very nearly so, but the mixture is black. Add to the mixture, by degrees, some muriatic acid, which will cause it to lose its blackness, and become transparent; add to this compound a strong solution of potash, which is colourless, and it will recover its blackness.

Mix an ounce of nitre with six drachms of black oxide of manganese, and expose the mixture to a red heat in a crucible. Take a dark-coloured mass thus prepared, and when

cold, put it into a glass vessel, pour a little water upon it, and the colour will be green; add more water, and the colour becomes blue; a further quantity makes it *purple*. The sulphuret of lime destroys its colour.

If calomel, which is white, be rubbed in a mortar with a solution of caustic ammonia, which is also without colour, the mixture becomes a deep black.

To a tincture of litmus or violets, or any other vegetable blue, add some diluted sulphate of indigo; the mixture will immediately become *red*.

Form a colourless solution of nitrate of copper in water; add to it liquid ammonia (spirits of hartshorn) which is also colourless, and the mixture will exhibit a deep blue colour.

APPENDIX.

On the Preparation and Use of Copal Varnish as a Vehicle preferable to Oil for the purposes of the Painter, and of a Varnish for Drawings and Prints.*

By the following process, a fine solution of copal in spirits of turpentine may be prepared without heat. It is quite transparent, colourless, durable, and protects colours from change.

Take the cleanest and whitest lumps of copal; beat them small, and pick out all the impurities. Pound them to a fine mass in a glass or Wedgwood's mortar; then pour in colourless spirits of turpentine to about one-third higher than the copal, and work up the whole quite fine. In half an hour work it up again till fine (if left too long it will get so tough as not to be rubbed up again;) and in an hour work it up again, and once or twice more in the course of the day. The next morning it may be poured off into a bottle for use; but as it is thicker or thinner according to the quantity of turpentine and the heat of the weather, it should be tried as follows before it is bottled up: dip a palette-knife into it, and dry the varnish adhering to the knife by the fire as quickly as you can without burning it; and if, when cold, a fair coat of varnish is found to be left on the knife, it is strong enough: otherwise work it up again, and let it stand some time longer. After taking off this first supply, pour on a fresh quantity of turpentine, and rub it up several times during two or three days:—try it by the palette-knife as before; and when strong enough, pour the liquid off into the same bottle with the first. A third quantity of the spirits might be added, which would

* Proposed by Varley, in Phil. Mag. v. 51.

make the remaining copal appear as dry as crumb of bread, and a much longer time would be required for the solution.

The common spirits of turpentine seems to dissolve copal best; but when that cannot be had colourless, the rectified spirits may be employed.

To paint with this varnish, use powder colours ground quite fine; or else grind them in spirits of turpentine, and add as much of the varnish as will bind them well. Keep them in bottles, and for use mix the tints in saucers, thinning them with pure spirits of turpentine as they thicken in drying. It is best to make the varnish so thin as not to shine when the paint is dry; but if it work too dry, moisten with a little more varnish till that fault be rectified; and if it become too thick, so as to work gummy, add powder colour and spirits of turpentine till it is brought to a proper consistence. The saucers of colours, if arranged in a small chest of drawers, will be kept clean, and in a small compass; and the colours will be continually set for use, as they only require moistening in the morning with spirits of turpentine; or without waiting to soften them in this way, fresh colour out of the bottles may be put upon the old.

The colours work freest, and dry quickest, when they do not shine, and will remain exactly as they are laid on; but if there is too much varnish, and the canvass is painted frequently over in the same day, the sharp touches will spread a little;—a fault which must be avoided by using no more varnish than just enough to shine, and by drying the part more perfectly before painting on it. In cold weather the drying may be effected by the fire, or by holding a hot iron before the canvass; in cold weather also, the painting must not be exposed to a fire directly after a part of it is done, as it would melt and run, but it should be suffered to dry for two or three hours, and then be brought to the fire to finish. To ensure the purity of the materials, the picture may be varnished with the same varnish made thicker; and when varnished, it should be dried as soon as convenient, by approaching the fire, avoiding a heat that would melt the copal. After this perfect drying, no dirt or smoke will ever stick to the picture; but it may be dusted, or may be washed quite clean with pure water, and will never change.

Another copal varnish may be prepared as follows: Take the sediment of the first varnish, or fresh copal beaten small; cover it to about twice its height with spirits of turpentine in which camphor, in the proportion of an ounce to a quart, is dissolved, cork it up, shake it well, and put it by for a year, at the end of which time it will be dissolved. The first por-

tion that is dissolved thickens the spirits of turpentine, and enables it to dissolve the remainder; but if the spirits of turpentine be too much diluted, the remainder will never dissolve, so that it is easier to make thick camphor varnish than thin. It must not, however, be made too thick, but when that which is put by is thick enough, pour it off for use, and add fresh camphor and spirits of turpentine to the remainder, and put it by again till dissolved, which it will be in the course of time. If the mixture put by be wanted before the copal is quite dissolved, it may be put into a saucepan of cold water, with the cork loosened, and made to boil for an hour, stirring it thoroughly two or three times towards the end of the boiling, and the solution will be finished.

Small pictures may be painted on the finest mill-board glued to a deal frame; and care should be taken to prevent large pictures from swagging, by not allowing the canvass to be tightened afterwards, but cutting the picture off the frame on which it was painted, and then pasting it to very tight canvass, protected by pannels from swagging and eventual cracking.

A third varnish is quickly made by oil of spike-lavender, which is very good for drawings or prints, but will not do for pictures, as it will dissolve the paint underneath, and run down while drying.

Method of preparing Ivory Paper, for the use of Miniature Painters.

The properties which render ivory so desirable a substance for the miniature painter and other artists are, the evenness and fineness of its grain; its allowing all water colours laid on its surface to be washed out with a soft wet brush, and the facility with which the artist may scrape off the colour from any particular part, by means of the point of a knife or other convenient instrument, and thus heighten and add brilliancy to the lights in his painting, more expeditiously and efficaciously than can be done in any other way.

The objections to ivory are its high price, the impossibility of obtaining plates exceeding very moderate dimensions, the coarseness of the grain of the larger plates; its liability, when thin, to warp by changes of the weather, and its property of turning yellow by long exposure to the light, owing to the oil which it contains.

* The method of preparing ivory paper, which combines the excellencies without the defects of ivory, is as follows: Take a quarter of a pound of clean parchment cuttings, and put them into a two-quart pan, with nearly as much water as it will hold; boil the mixture gently for four or five hours, adding water from time to time to supply the place of that driven off by evaporation; then carefully strain the liquor from the dregs through a cloth, and when cold it will form a strong jelly, which may be called size No. 1.

Return the dregs of the preceding process into the pan, fill up the pan with water, and again boil it as before for four or five hours: then strain off the liquor, and call it size No. 2.

Take three sheets of drawing paper, (outsides will answer the purpose perfectly well, and being much cheaper, are therefore to be preferred) wet them on both sides with a soft sponge dipped in water, and paste them together with the size No. 2. While they are still wet, lay them on a table, and place upon them a smooth slab of writing slate, of a size somewhat smaller than the paper. Turn up the edges of the paper, and paste them on the back of the slate, and then allow the paper to dry gradually. Wet, as before, three more sheets of the same kind of paper, and paste them on the others, one at a time; cut off with a knife what projects beyond the edges of the slate, and when the whole has become perfectly dry, wrap a small flat piece of slate in coarse sand-paper, and with this rubber make the surface of the paper quite even and smooth. Then paste on an inside sheet, which must be quite free from spots or dirt of any kind; cut off the projecting edges as before; and when dry, rub it with fine glass paper, which will produce a perfectly smooth surface. Now take half a pint of the size No. 1, melt it by a gentle heat, and then stir into it three table-spoonfuls of fine plaster of Paris; when the mixture is completed, pour it out on the paper, and with a soft wet sponge distribute it as evenly over the surface as possible. Then allow the surface to dry slowly, and rub it again with fine glass paper. Lastly, take a few spoonfuls of the size No. 1 and mix it with three-fourths its quantity of water; unite the two by a gentle heat, and when the mass has cooled, so as to be in a semi-gelatinous state, pour about one-third of it on the surface of the paper, and spread it evenly with the sponge when this has dried, pour on another portion, and afterwards the remainder: when the whole has again become dry, rub it over lightly with fine glass paper, and the process is completed; it may accordingly be cut away from the slab of slate, and is ready for use.

The quantity of ingredients above mentioned is sufficient for a piece of paper 17½ inches by 15½ inches.

Plaster of Paris gives a perfectly white surface; oxide of zinc, mixed with plaster of Paris, in the proportion of four parts of the former to three of the latter, gives a tint very nearly resembling ivory; precipitated carbonate of barytes gives a tint intermediate between the two.

The sum of thirty guineas was voted by the Society for the Encouragement of Arts, &c. to S. Einsle, of Strutton-Ground, Westminster, for the communication of his method of making ivory paper, as above described. Specimens of the ivory paper were produced to the Society; they were about the eighth of an inch thick, and of superficial dimensions much larger than the largest ivory: the surface was hard, smooth, and perfectly even. It appeared on a trial of these specimens by some of the artists, members of the Society, that colours may be washed off the ivory paper more completely than from ivory itself, and that the process may be repeated three or four times upon the same surface, without rubbing up the grain of the paper. The ivory paper also, with proper care, will bear to be scraped with the edge of a knife, without becoming rough.

Traces made upon the surface of this paper by a hard black-lead pencil are much easier effaced by means of Indian rubber than from common drawing paper, which circumstance, together with that of the extremely fine lines which its hard and even surface is capable of receiving, peculiarly adapts it to the reception of the most delicate kind of pencil drawings and outlines.

An artist of eminence in miniature painting (not a member of the Society) stated, that he has frequently used the ivory paper, and finds it to be superior to ivory itself in the whiteness of the surface, in the facility with which it receives colour, and in the greater brilliancy of the colours when laid on, owing to the superior whiteness of the ground. Colours on ivory are apt to be injured by the transudation of the animal oil, a defect from which the ivory paper is free.

Some highly respectable dealers in drawing materials stated, that they had had samples of the ivory paper in their possession for a considerable time, and that it did not appear to become yellow or discoloured by keeping.

Method of making artificial Stone, and moulding it as a substitute for Portland-Stone Chimney-Pieces.

Take two bushels of sharp drift sand, and one bushel of sifted slacked quicklime; mix them up together with as little water as possible, and beat them well up together for half an hour every morning, for three or four successive days, but never wet them again after their first mixture.

To two gallons of water, contained in a proper vessel, add one pint of single size, made warm; a quarter of a pound of alum, in powder, is then to be dissolved in warm water, and mixed with the above liquor.

Take about a shovelful of the first composition, make a hole in the middle of it, and put therein three quarters of a pint of the mixture of alum and size, to which add three or four pounds of coarse plaster of Paris; the whole is to be well beaten, and mixed together rather stiff; put this mixture into the wooden moulds of the intended chimney-piece, the sides, ends, and tops of which moulds are to be made of moveable pieces, previously oiled with the following mixture:

Take one pint of the droppings of sweet oil, which costs about one shilling the pint, and add thereto one pint of clear lime-water, made by pouring boiling water on lumps of chalk lime in a close vessel till fully saturated; when the lime-water becomes clear, it is proper to be added to the oil as abovementioned, and the two fluids, on being stirred together, will form a thick oily mixture or emulsion, proper to apply upon the moulds.

In forming the side or jamb of a chimney-piece, the mould is to be first half filled with the sand-lime and plaster composition; then two wires wrapped round with a thin layer of hemp, and which wires are nearly the length of the piece to be moulded, are to be placed in parallel lines lengthways, in the mixture or composition in the mould, and afterwards the mould is filled up with more of the composition; and if there is any superfluous quantity, it is to be struck off with a piece of flat board.

The lid or top part of the mould is to be then placed upon it, and the whole subjected to a strong pressure from weighted levers or a screw press. The composition is to remain under this pressure for twenty or thirty minutes; the precise time necessary may be known, from examining a small specimen

of the composition reserved purposely to determine the time it requires to harden and set firm.

The sides of the mould are to be held together by iron clamps and wedges.

The wires above mentioned answer a double purpose, by giving strength to the jambs, and retaining the whole mass together in case it should at any time be cracked by accident.

The chimney-pieces may be made either plain or fluted, according to the mould; and when moulded, they are finished off by rubbing them over with alum water, and smoothing them with a trowel and a little wet plaster of Paris.

A common plain chimney-piece of this composition is sold for seven shillings, and a reeded one for twenty-eight shillings, completely fitted up.

Architectural Cement to resist the filtration of Water.

The following cement, invented by Thenard, an eminent French chemist, has been used with great success in covering terraces, lining basins, soldering stones, &c. and it everywhere resists the filtration of water; it is so hard that it scratches iron. It is formed of

93 parts of well-burnt brick or clay.
7 parts litharge and linseed oil.

100

Nothing can be more simple than its composition, or the manner of using it. The brick and litharge are pulverized; the latter must always be reduced to a very fine powder; they are mixed together, and enough of linseed oil is added to the mixture to give it the consistence of thin plaster. It is then applied in the manner of plaster, the body that is to be covered being always previously wetted. This precaution is indispensable, otherwise the oil would filter through the body, and prevent the mastic from acquiring the desirable degree of hardness. When it is extended over a large surface, it sometimes happens to have flaws in it, which must be filled up with a fresh quantity of the cement. In three or four days it becomes firm.

A fire-proof and water-proof Cement.

To half a pint of milk put an equal quantity of vinegar, in order to curdle it; then separate the curd from the whey, and mix the whey with the whites of four or five eggs, beating the whole well together. When it is well mixed, add a little quick lime through a sieve, until it has acquired the consistence of a thick paste.

With this cement, broken vessels and cracks of all kinds may be mended; it dries quickly, and resists the action of water, and of fire applied to vessels containing water.

A *Cement withstanding Sulphuric Acid*, will be found at page 788.

Method of preparing the celebrated Chunam of India, as practised at Madras.

Take 15 bushels of pit sand, and 15 bushels of stone-lime; slake the lime with water; and when it has fallen to powder, mix the two ingredients together, and let them remain untouched for three days. In the mean time dissolve 20lbs. of molasses in water, boil a peck of gramm (a kind of pea) to a jelly, boil a peck of mirabolans also to a jelly, mix the three liquors, and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement: some short tow is now to be beaten very well into it, and it is then fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar; and when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor before the application of any fresh mortar. When this is used for stucco, the white of four or five eggs, four ounces of butter or sesamum oil, and a pint of buttermilk, are to be mixed up with every half bushel of cement, and the composition is to be applied immediately.

A Varnish for Metals resisting the combined action of air and acid Vapours.

Lampadius, professor of chemistry at Freyberg in Saxony, having remarked that the sulphurous and acid vapours which rise from the furnaces for smelting ores, destroy in a short time the ordinary varnishes, and attack the metals used in the construction of buildings, studied to discover a coating which would resist their action. As it was necessary to oppose to the acids, a matter which they could not dissolve, he tried the metallic oxides of lead and zinc, when saturated with sulphuric acid. These oxides, from their desiccative quality, are well adapted to the composition of varnish, and are easily obtained. Sulphate of lead is prepared by mixing a solution of four ounces of acetate of lead in twelve ounces of water, with a solution of seven ounces of sulphate of soda in fourteen ounces of water. The precipitate obtained by this mixture is sulphate of lead, which is to be filtered, edulcorated, and dried. Sulphate of zinc is sold by chemists and druggists under the name of white vitriol of zinc.

The method of preparing the varnish is as follows: Reduce to an impalpable powder one ounce of plumbago, with which mix four ounces of sulphate of lead, and one ounce of sulphate of zinc, and add to it by degrees, one pound of varnish, prepared with linseed oil, previously heated to ebullition. This varnish dries quickly, and perfectly preserves from oxidation the metals coated with it. It has been employed with success to cover lightning conductors, and, after a trial of many years, has been found to answer equally well for roofs covered with lead, iron, copper, or zinc, which are continually exposed to the action of damp and of acid vapours.

Account of Experiments on the utility of Salt as a Manure, and as a Condiment mixed with the food of Animals.*

On the value of salt as a manure the public opinion has been much divided; the advocates for the use of salt, reasoning

* For this Essay, Dr. Edmund Cartwright of Woburn received the Gold Medal of the Board of Agriculture.

from the striking effects of salt-water on the marshes, which are occasionally irrigated by the sea at spring-tides, conclude that the fertilizing virtue of such irrigation is owing to its saline quality, without taking into consideration the quantity of animal and vegetable matter which sea-water (particularly near the coast, and where rivers disembogue themselves,) must necessarily hold in solution.

To determine the question, a soil* was selected well calculated to give impartial results, from its containing no ingredient (a small portion of oxide of iron excepted—about 7 grains in 400 of the soil) of sufficient activity to augment or restrain the peculiar energies of the substances employed. A certain portion of this soil was laid out in beds one yard wide and forty long. The beds were planted with potatoes, a single row in each bed, and the same number of sets in each. To one bed no manure was used, to ten other beds a single different manure, and to other fourteen beds, the manures were mostly compounded of these. Of the single manures, the quantity used of each was,

Of Salt, a quarter of a peck,
Lime, one bushel,
Soot, one peck,
Wood-ashes, two pecks,
Saw-dust, three bushels,
Malt-dust, two pecks,
Peat, three bushels,
Decayed leaves, three bushels,
Fresh dung, three bushels,
Chandlers' graves, nine pounds.

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* The soil was a ferruginous sand, which had been brought to a due texture and consistence by a liberal covering of pond mud:

	grains
400 grains gave of siliceous sand of different degrees of fineness, about	280
Of finely divided matter, like clay	104
Loss in water	16
	400

	grains
The 104 grains of finely divided matter contained of carbonate of lime	18
Of oxide of iron	7
Loss by incineration, most probably from the decomposition of vegetable matter	17
The remainder principally silex and alumine.	

When these manures were mixed, the quantity of each ingredient was the same as when used singly. The potatoes were planted on the 14th of April, 1804; on the 21st of September following they were taken up, and the produce of each row was in succession as follows:

Salt and soot produced	240
Chandlers' graves	220
Salt, wood ashes	217
Salt, gypsum, peat, lime	201
Salt, lime, dung	199
Salt	198
Salt, graves	195
Soot	192
Fresh Dung	192
Salt, malt-dust	189
Wood ashes	187
Salt, decayed leaves	187
Salt, peat ashes	185
Malt-dust	184
Salt, lime, peat	183
Salt, saw-dust	180
Salt, peat, bone-dust	178
Decayed leaves	175
Salt, lime, sulphuric acid	175
Salt, peat	171
Salt, lime	167
Peat	159
No manure	157
Saw-dust	155
Lime	150

The foregoing table furnishes many particulars worthy of observation. In the first place, it is remarkable, that of 10 different manures, most of which are of known and acknowledged efficacy, salt is superior to them all, one only excepted. And again, when used in combination with other substances, it is only unsuccessfully applied in union with one, viz. chandlers' graves, no other manure seemingly being injured by it. Possibly its deteriorating effects on chandlers' graves may be owing to its antiseptic property, which retards the putrefactive process by which animal substances undergo the changes necessary to qualify them to become the food of plants.

The extraordinary effects of salt, when combined with soot, may not be owing to any known chemical agency of these sub-

stances on each other, but is perhaps attributable to the property of saline substances by which they attract moisture from the atmosphere. Those beds where salt had been used were visibly and palpably moister than the rest, even for weeks after the salt had been applied; and this appearance continued till rain fell, when of course the distinction ceased. This property of attracting moisture, had greater influence possibly on the soot than on any of the other manures, as soot, from its acrid and dry nature, may be supposed to require a greater proportion of water to dilute it than those substances which contain water already. On those beds where salt had been used, the plants were obviously of a paler green, though not less luxuriant. It was observable also, that where salt was applied, whether by itself or in combination, the roots were free from that scabbiness which oftentimes infects potatoes, and from which none of the other beds, (and there were in the field nearly forty more than what made part of these experiments) were altogether exempt.

From two sets of experiments made on a very poor soil, it appeared that a due texture and consistence in the soil is as necessary to the health and existence of vegetables as the pabulum by which they are sustained; those manures being the most efficacious, which, in the soil employed, contributed to produce this texture and consistence.

As a condiment, the effects of salt were tried upon hogs, about a quarter of a pound per day being mixed with their food. It did not appear that the salt had any operation, either in promoting thirst or stimulating their appetites, the consumption of food being nearly the same whether salted or not, neither does it appear that the salt had any influence on their fattening. The author observes, *en passant*, that for most of the internal disorders to which hogs are liable (and they may all be supposed to be more or less accompanied with fever) he has found no remedy so efficacious as antimony, in the form of emetic tar; from 5 to 40 or 50 grains may be given, according to the age and strength of the animal, and probably larger doses may be perfectly safe.

In trying the effect of salt upon cows, these animals had salt mixed with their hay, which was first slightly moistened with water, and then sprinkled with salt, of which they consumed about half a pound per day. While they were thus supplied with salt, they drank about three gallons per day more than at other times, and they gave rather more milk; but when the increased quantity of milk is balanced against the price of the salt, the dairyman will find himself no gainer.

As most if not all graminivorous animals, whether wild or domesticated, are known to eat salt with avidity, whenever it comes in their way, it is reasonable to suppose that the propensity has not been implanted in them in vain. Perhaps the use of salt will be found beneficial principally in contributing to the health of animals by aiding their digestion.

On the efficacy of Burnt Clay as a Manure, and an economical Method of burning large Quantities of Clay.

The following account of the efficacy of burnt clay as a manure, and of the method of burning it, is by the same author as the one of which we have last given a summary. It was rewarded by the gold medal of the Society for the Encouragement of Arts, &c.; and developes a system of agricultural management, which to many extensive districts will be of so much consequence, that it cannot be too generally known.

For some years past, says Dr. Cartwright, I have been in the practice of using soot and wood-ashes, as top-dressings, but never to much extent, from the difficulty of procuring them in any considerable quantity. In the spring of this year, (1819,) I was enabled to obtain soot to top-dress between five and six acres; part pasture and part arable, after the rate of 50 bushels per acre; and wood-ashes sufficient for the same quantity of ground, after the rate of 100 bushels per acre. The prime cost of the soot was 9d. per bushel; but as I had to fetch it from some distance, I calculate the price of it, when brought home, at 1s. per bushel. The wood-ashes were 4½d. per bushel; but as they lay nearer home, I reckon the carriage at 1½d. per bushel. The expense, therefore, of top-dressing, with each of these articles, was the same, namely £2. 10s. per acre. The object of my experiment this year was, to compare burnt clay, soot, and wood-ashes.

With burnt clay I top-dressed about seven acres, after the rate of 20 cart-loads per acre, each cart-load being about 20 bushels. I must here observe, that when I first began the burning of clay, I found it a very difficult and expensive business, but I have latterly contrived a method of performing the operation at a very cheap rate. It does not now cost me more than 9d. per cart-load, fuel included, provided the weather is not unfavourable; so that the expense of this manure does not exceed 15s. per acre.

The soil on which these top-dressings were applied, was a cold, wet, tenacious clay. The crops on which they were tried were Swedish turnips, the common turnip, kohlrabi, turnip-rooted cabbage, potatoes, mangel-wurzel, barley, and beans.

On the 15th September, I measured off 50 square yards of Swedish turnips, under each top-dressing, and 50 square yards which had not been top-dressed. Their respective weights were as follows:

	lb.		ton.	cwt.	lb.
Burnt clay, - -	580	per acre - -	25	2	20
Soot, - - - -	546	- - - - - -	23	12	2
Wood-ashes, - -	398	- - - - - -	16	12	52
No top-dressing,	235	- - - - - -	10	3	12

Taking the value of the turnips at only 5s. per ton, (and they certainly are worth more,) the burnt clay exceeds the soot in value of crop per acre 7s. 6d. by saving in prime cost £1. 15s. total £2. 2s. 6d. The superiority of burned clay over wood-ashes is nearly 8½d. to the value of which, if the saving in prime cost is added, the superiority will be £3. 17s. 6d.

The superiority of burnt clay over that which had no top-dressing, will, in money (deducting the expense of burning the clay) be £4. 7s. 6d.

I must here observe, that the great disparity between the turnips which were top-dressed, and those which were not, must not be attributed altogether to the fertilizing properties of the substances employed, but in a considerable degree to the protection they afforded the young plants from the depredation of the fly. This will appear by the subsequent experiments on the kohlrabi and the common turnip. The kohlrabi plants, destroyed by the fly, were replaced from a seed-bed. As the transplanting was performed in a showery time, none of them failed. The common turnip was sown during the same favourable weather, and escaped the fly altogether.

On the 7th of October, I measured off 50 square yards of potatoes, top-dressed with burnt clay, &c. The results were as follows:

	bush.	pecks.		bush.
Burnt clay, - - -	5	0	per acre, - -	480
Soot, - - - - -	4	3	- - - - - -	456
Wood-ashes, - -	4	2	- - - - - -	432
No top-dressing, -	4	0	- - - - - -	340

On the 4th of November, the results of similar experiments on kohlrabi, were as follows:

	lb.		ton.	cwt.	lb.
Burnt clay, - -	160	per acre - -	6	17	26
Soot, - - - -	138	- - - - - -	3	18	32
Wood-ashes, - -	114	- - - - - -	4	17	30
No top-dressing,	93	- - - - - -	4	7	48

In my experiments on Reynold's turnip-rooted cabbage, and on mangel-wurzel, I was completely defeated: of the former I had the seed by me for many years, and it had outlived its power of vegetating, and the mangel-wurzel had never acquired that power, the cold wet season of last summer not suffering it to ripen.

Having only half an acre of barley, I divided it into four equal parts. Not having conveniency in my small barn to keep the produce of each by itself, I kept an account of the number of sheaves that each part produced. When the whole was threshed out, I divided the grain that it yielded, which amounted to two quarters, into four parts, proportionate to the number of sheaves reaped from each division.

	sheaves.		bush.	pecks.		qr.	bush.
Burnt clay, -	126	- - -	4	2	per acre - - -	4	4
Soot, - - -	121	more than	4	1	rather more than	4	2
Wood-ashes,	117	less than	4	1	rather less than	4	2
No top-dressing	84	- - -	3	0	- - - - - -	3	0

It must be observed, that the barley was sown in alternate rows with beans, so that, in fact, the space occupied by the barley ought not to be reckoned more than a quarter of an acre, as one-half of the ground produced a crop of beans. Of the result of the experiment on the beans, I am not able to speak, as when put into the barn, they accidentally got mixed with others.

November 7th. The result of the experiment with common turnip was as follows:

	lb.		ton.	cwt.	lb.
Burnt clay, - -	296	per acre, - -	6	7	54
Soot, - - - -	292	- - - - - -	6	5	36
Wood-ashes, - -	293	- - - - - -	6	5	36
No top-dressing,	276	- - - - - -	5	16	76

Why the result of this last experiment should vary so much from the preceding ones, I am at a loss to conjecture. Had I not paid the most minute personal attention to every individual part of the experiments, from their commencement to the final measuring off and weighing the produce, I might suspect, indeed, that my directions had been deviated from or neglected, but as this could not possibly have been the case, the result of this last experiment must be set down as one of the many anomalies that are perpetually arising to baffle human ingenuity.*

Of the experiments on grass land, I had no convenient way of judging, but by the eye. As far as the eye could decide, the burnt clay was, without question, the superior; and the soot, as in all the other experiments except the last, was evidently more powerful than the wood-ashes. It is singular, that in the neighbourhood where I reside, (near Tunbridge) the farmers hold soot in very light estimation, but have a very high opinion of wood-ashes; an opinion which these experiments may tend to rectify. Burnt clay, it will clearly appear by these diversified experiments, has the most decided advantage over the other two substances in every respect: its immediate effect is greater, its original cost is less, and in durability it admits not of a comparison. It is universally admitted, that wherever burnt clay has been applied on a cold, wet, adhesive soil, it makes an immediate alteration in the texture of it, rendering it dry and friable, so as to admit of its being worked at almost all seasons. I gave a dressing of burnt clay to a small piece of ground, between seven and eight years ago, the effect of which is visible to this day, and probably will be for some years to come.

Burnt clay has been used as manure in Ireland with the greatest success for at least a century past; has been introduced into Scotland with equal advantage within the last ten years; and it is now beginning to get footing in England, where this exposition of facts, in proof of its utility, will, it is hoped, accelerate its adoption. As soon as its use is universally established, we may date a new, and indeed, a brilliant era in the history and progress of British husbandry. This is not said at random, but from a confident persuasion, in which the opinions of some of our best agriculturists will bear me out, that the judicious application of burnt clay, on soils to which it is adapted, will in a few years double their present value.

* Dr. Cartwright had afterwards reason to suppose that the anomaly which so much surprised him, was in consequence of the thinning the crop received from the depredations of gipseys or other vagabonds.

When I first began to burn clay, which is now three years ago, I followed such printed directions as I met with in different publications on the subject. I never, however, was able to accomplish my object but at an expense greater than what I could have purchased stable manure for. I determined, therefore, to try if I could not burn it at a cheaper rate.—After a variety of experiments, which it would be useless to detail, I adopted the following method:—I had a trench made, about 20 feet long, three feet deep, and as many wide, with sufficient fall for taking off the water. At the upper end of the trench, and resting on its sides, a brick arch was turned, about 9 or 10 feet long, having openings for letting the fire through to the clay. These openings were made by leaving out half a brick at proper intervals. In the front of the arch is a strong wall two bricks thick, which has its foundation in the bottom of the trench. This wall, which is two feet wider than the arch, rises about a foot above it, through which there is a mouth to the arch about two feet wide. The whole erection will not require above 5 or 600 bricks, and no lime, except for the front wall. The arch will be best laid in loam or puddle of any kind.

In setting the kiln, care should be taken, especially at the commencement of the business, to lay the sods, or lumps of clay, hollow, that the fire may draw through freely. When the pile is about two feet thick upon the arch, the fire should be lighted, and a sod wall made round the kiln, which may extend about 2 feet wider than the arch, which will be supported in front of the brick wall. The sod wall will not be above 3 or 4 feet high. As the ignition proceeds, fresh clay must be added, still letting it lie as hollow as conveniently may be. When the heap is between four and five feet high, and burned through, the fire may be suffered to die out. Clay, however, may still be added for a day longer at least, and the more crumbly part of the clay may now be used. Two men, at 2s. 6d. per day, and a boy at 6d. per day to attend the fire, in 2½ days burned 35 good cart loads, the fuel consumed was 175 furze faggots at 5s. per hundred; the expense therefore stands thus:

	£	s.	d.
Labour, - - - - - - - - - - - - - - - -	£0	14	0
Fuel, - - - - - - - - - - - - - - - - -	0	8	9
To which may be added a donkey and cart two days,	0	3	0
	£1	5	9

I need not observe, that the divisions of the arch, &c. are merely arbitrary. My farm being a very small one, small kilns

answer my purpose. I mean to have two, that one may be at work while the other is cooling. I may further observe, that the consumption of fuel will of course be regulated by the state of the weather. Those who do not chuse to go to the expense of a brick or stone arch, may make one of sod or spits of clay, (but in this case they must be perfectly dry, or else they will not support the superincumbent weight.) The centre for this kind of arch is thus made:—Lay four or five strong stakes across the trench, and upon these lay faggots, in a circular form, to build the arch upon. When the work is finished, the centre of faggots is set fire to. Though a trifling expense is thus saved in the first instance, a brick or stone arch will be found in the end cheaper, as the sod or clay arch must be renewed every time.

Method of purifying Corn, when tainted with Must.

The following very simple and efficacious mode of purifying corn tainted with must, was discovered by Charles Hatchett, F. R. S.

Put the wheat into any convenient vessel capable of containing at least three times the quantity, and the vessel must subsequently be filled with boiling water; the grain should then be occasionally stirred, and the hollow and decayed grains (which will float) may be removed. When the water has become cold, or in general when about half an hour has elapsed, it is to be drawn off. It will be proper then to rinse the corn with cold water, in order to remove any portion of the water, which had taken up the must; after which, the corn being completely drained, is without loss of time to be thinly spread on the floor of a kiln, and thoroughly dried, care being taken to stir and turn it frequently during this part of the process.

New Method of making Bread.

New flour which has not been perfectly harvested, will not it is well known, make light and wholesome bread. For this defect, an eminent chemist, Edmund Davy, of Cork, has dis-

covered a corrective, which promises, after unfavourable seasons particularly, to be of great importance. It consists in mixing intimately with each pound of the flour, from twenty to forty grains of the carbonate of magnesia of the shops. Not the slightest danger can be apprehended from the use of such an innocent substance as carbonate of magnesia in the small proportion requisite for this purpose, and it produces a very remarkable effect in improving the lightness and taste of the bread.

On burning Lime with Peat.

From a communication by —— Dodgson, of Grahamonset, in Cumberland, to the Board of Agriculture, it appears that the quickness of the process of burning lime with peat is surprising, for in twelve hours after putting fire to the kiln, the lime is ready to draw: in burning with coal, none can be drawn for two or three days; and nearly double the quantity of lime is produced every succeeding day that can be with the use of coal, owing to the peat keeping the limestone in an open porous state, and admitting a brisk circulation of the air. For the same reason, the limestone cannot be run into a solid lump, by excessive heat, as sometimes happens with coal. Peat only half dry, will burn lime as well as when thoroughly dry, only the process of burning is a little slower.

On the Prevention of the Dry Rot in Timber.

Gavin Inglis, in some observations on the prevention of dry rot, concurs in opinion with others who have recently published the results of their experience on the subject, that timber, especially for ship-building, ought never to be cut till after the fall of the leaf, when it contains the least sap and moisture. He further observes, that in examining masses of oak, dug from the alluvial strata of the country, where it has lain for ages, many of them are found fresh and sound as they could have been on the day they were overthrown. In these cases, the timber is uniformly as black as ebony, and obdurately hard. Having been led from curiosity to examine chemically several of these

old trunks, he found them to contain a far greater proportion of iron than could be supposed to have existed in the natural state of the tree. To this extraneous iron may be attributed the incorruptibility of antediluvian timber; and it must have been supplied by the ore of the soil, or from chalybeate waters; in this state of solution, it would penetrate the substance of the wood, unite with the astringent principle, and produce not only the black colour, but such a density of texture as almost to resist the sharpest instrument. The same means will season new timber, and render it proof against dry rot, that will cure old; namely, the application of iron in a state of solution. This can be obtained, at a comparatively small expense, from a solution of sulphate of iron (green copperas) in which the wood must be soaked till it has acquired the colour of new ink. This would completely counteract every vegetable principle, and communicate durability and firmness of texture, with the additional advantage, that the sulphur of the solution, penetrating the substance of the plank, would defend it from the ravages of insects.

New Methods of making single Microscopes of Glass.

The following methods of making single microscopes of glass, are the invention of Thomas Sivright, F. R. S. E.

Take a piece of platinum leaf, about the thickness of tinfoil, and make two or three circular holes in it, from one-twentieth to one-tenth of an inch in diameter, and at the distance of half an inch from each other. In the holes put pieces of glass, which will stick in them without falling through, and which are thick enough to fill the apertures. When the glass is melted at the flame of a candle with the blowpipe, it forms a lens which adheres strongly to the metal, and the lens is therefore formed and set at the same time. The pieces of glass used for this purpose should have no mark of a diamond or file upon them, as the mark always remains, however strongly they are heated with the blowpipe. An eye or loop, made by bending the extremity of a platinum wire, may be used instead of platinum leaf.

The lenses which were made larger than one-tenth of an inch were not so good as the rest, and the best were even of a smaller size than one-tenth. They are produced with great facility, and it is advisable to make a greater number than may be required, selecting only the best to be kept for use.

Platinum is infusible at the heat required for the perfect fusion of glass; it may therefore be used very thin for this purpose; and as it does not oxidate, the glass adheres firmly to it.

Plano-convex lenses may be obtained by fusing with a strong heat, a fragment of glass resting upon a polished plane of topaz, obtained by the fracture of that stone. A blowpipe urged by common air only is required; one supplied with oxygen gas would act upon the topaz.

Indelible Ink for marking Linen

The purple precipitate of Cassius (see page 367 of this vol.) is used in Italy as an indelible ink, which is recommended as much superior to that of silver. That part of the linen on which the writing is to be, must first be moistened with a solution of recently made muriate of tin, and when dry the writing is to be done with a solution of gold, and then washed in water. The writing, which will become black, is not at all affected by washing, and with great difficulty by other agents, and not before the cloth is destroyed.

Method of preparing incorruptible Writing Ink.

The following directions for preparing incorruptible writing ink, are given by Van Mons, an eminent foreign chemist, and the discovery is certainly one of very considerable merit. I have succeeded, says he, in depriving ink of its principle of corruption, by infusing the gall-nuts in common beer vinegar. They are to be broken into coarse powder, and infused for two or three days in a retort closed with a piece of paper. The infusion is then passed through a woollen sieve; the residue washed in cold water, decanting all that remains suspended in the water; the latter portion is then to be infused in the same manner in pure water, and both infusions are to be mixed. The whole is to be heated for an instant, and then allowed to subside for twenty-four hours, when it is to be filtered again; gum and sugar are then to be added, and when they are dissolved, the whole is to be once more passed through the sieve.

The ink is then to be mixed with the oxide or red sulphate, but neither the acidulated nor oxidulated sulphate ought to be used. The whole being shaken, may be put into a stone-bottle, and corked with a paper stopper.

Not only is the ink thus obtained prevented from corrupting, but it loses another bad property, namely, that of thickening. The acid of the vinegar is combined as a mucous kind of acetate, with the mucilaginous matter, and precipitates it; the vinegar is very much softened in this infusion by the connexion which its acid parts form with the mucus. The thickening of the ink arises from the sulphuric acid rendered free, precipitating this body. The mucus of the gum arabic scarcely undergoes this change at all.

For the proportions of the ingredients in writing ink, and other particulars not mentioned in this general account, we refer to page 781 of this volume.

Yellow Sympathetic Ink.

At page 784 of this volume, we have given some of the best processes for preparing what are fancifully denominated sympathetic inks: the present article will make a curious addition to the number.

Dissolve an ounce of sulphate of copper, and another of muriate of ammonia, in six ounces of water, diluting the solution gradually with more water, till it ceases to leave a visible trace upon paper after having been suffered to dry.

Writing executed with this ink is invisible when dry, but appears of a beautiful yellow by heating the paper, and disappears when the paper is cold.

Ignited Wire Lamp.

Sir Humphrey Davy, in the course of his admirable researches on flame, discovered a peculiar state of combustion at a heat below that of flame.

A coil of platinum wire, about one hundredth part of an inch in thickness, and containing from eight to fifteen or sixteen turns, is dropped on to the wick of a spirit lamp, so that

part touches the wick, and part remains supported above. On blowing out the flame of the lamp, after it has been lighted, the wire will remain ignited, and continue so as long as any spirit remains below.

It has been ascertained that camphor may be substituted for the alcohol, by introducing a cylinder of it in place of the wick; the ignition is very bright, and a pleasant odorous vapour arises from it.

Spirit of turpentine in the lamp also succeeds. The wire does not remain ignited; but the continuance of the effect is marked by the ascent of a dense line of vapour, which rises from the wire, and diffuses an odour by some thought agreeable.

Effects of Vapour on Flame.

J. F. Dana, chemical assistant in Harvard university, and lecturer on chemistry and pharmacy in Dartmouth college, has published in Professor Sillman's journal an essay on the effects of vapour on flame, affording hints well deserving the notice of practical men.

When a jet of steam issuing from a small aperture, is thrown on burning charcoal, the brightness is increased, if the coal be held at the distance of four or five inches from the pipe through which the steam passes; but if the coal be held nearer, it is extinguished; a circular black spot first appears where the steam is thrown on it. The steam in this case does not appear to be decomposed, and the increased brightness of the coal depends probably on a current of atmospheric air, occasioned by the steam. But when a jet of steam, instead of being thrown on a single coal, is made to pass through a charcoal fire, the vividness of the combustion is increased, and the low attenuated flame of coal is enlarged.

When the wick of a common oil lamp is raised, so as to give off large columns of smoke, and a jet of steam is thrown into it, the brightness of the flame is increased, and no smoke is thrown off.

When spirit of turpentine is made to burn on a wick, the light produced is dull and reddish, and a large quantity of thick smoke is given off; but when a jet of steam is thrown into this flame, its brightness is much increased; and when the experiment is carefully performed, the smoke entirely

disappears. When the vapour of spirits of turpentine is made to issue from a small orifice, and inflamed, it burns, and throws off large quantities of smoke; but when a jet of steam is made to unite with the vapour, the smoke entirely disappears. When vapour of spirit of turpentine and of water are made to issue together from the same orifice, and inflamed, no smoke appears. Hence its disappearing, in the above experiment, cannot be supposed to depend upon a current of atmospheric air.

When a jet of steam is thrown into the flame of a spirit-of-wine lamp, or into flames which evolve no smoke or carbonaceous matter, the same effect is produced as by a current of air.

It appears from these experiments, that in all flames which evolve smoke, steam produces an increased brightness. Now, with a very simple apparatus, steam might be introduced into the flames of street lamps, and into all flames which evolve much smoke. The advantage of such an arrangement would be, a more perfect combustion, and a greater quantity of light from the same materials. The flame of the lamps to which steam is applied might be made to keep the water boiling which supplies the steam.

Method of preserving Vegetable Remedies.

Let the fresh herb, intended to be preserved, be collected free from dew, and having rubbed the leaves into the finest pulp, let them be formed into a moderately consistent mass, by the addition and careful intermixture of white sugar, or dried soap. In this manner the vegetable may be long preserved, and the advantages are obtained of administering it throughout the year in its pristine state, and without previously subjecting it to any operation, or to the agency of any substance by which its properties may be enfeebled or destroyed. This process is proposed by Dr. Marshall Hall, who has successfully applied it to the preservation of the plants,—digitalis, cicuta, hyoscyamus, &c.

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